SPEECH AND THE REGULATION OF BEHAVIOUR

David Bloor

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SUMMARY

This thesis presents an examination of a theory about the function of language. The theory, proposed by L.S. Vygotsky and elaborated by A.R. Luria, is that language, in the form of self-instructions, plays a crucial role in the organisation of behaviour. For Vygotsky self-instructions help to set the goals of behaviour; Luria adds the claim that they also enter into the very organisation of the ongoing motor responses whereby those goals are achieved. These processes are held to be particularly important and prominent in young children.

Two levels of generality can be discerned in Luria's theory. On one level he proposes specific models (which are here dubbed the Feedback and Shunt models respectively) which account for certain features of the verbal regulation of behaviour. The first pair of experiments are designed to test two important assumptions of these models, namely that in young children the motor system suffers from a lack of proprioceptive feedback, and that the verbal system is in certain specific respects more highly developed than the motor system. Strong doubt is cast on these claims and alternative explanations are proposed for the observed results.

The investigation then passes on to a more general formulation of Luria's theory and searches for evidence
of verbal components in the organisation of motor responses. Some Skinnerian work allegedly providing this is reviewed and criticised; its shortcomings are used to suggest the focus of the next two experiments. These establish that self-instructions, whether overt or covert, can actively interfere with the conduct of a simple motor task like tapping. It is found, though, that the relative load of covert commands is less than that of covert countermands in 6 year olds. This may be an example of verbal self-regulation, though other possible explanations are considered.

The central experiments of this study also examine the effect of placing overt self-instructions in opposition to a motor set in young children (age 6), but this time in more complicated tasks. Ss responded by uttering one of two colour names and by pressing one of two coloured buttons to the forced-paced, serial presentation of two coloured light signals. The independent variables were, (i) speed of presentation, (ii) S-R compatibility, and (iii) R-R compatibility. The regulatory theory predicts more interference with the motor task than the verbal task. No such overall effect is found. Although in some situations the motor system suffers more disorganisation than the verbal system, in others it is the verbal system which appears to be dominated by the motor system. The crucial variable is found to be S-R compatibility. The experimental result presents severe difficulties for the
regulatory theory and so an alternative theory is proposed. This is based on considerations of limited channel capacity, and treats the verbal and motor systems as otherwise independent.
This dissertation is the result of my independent work. The material has not been submitted for any other degree.

David Bloor
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CHAPTER I

THE VYGOTSKY-LURIA THEORY OF VERBAL SELF-REGULATION

In his book *Thought and Language* the Soviet psychologist L.S. Vygotsky (1962) proposed the idea that the role of language in child development goes beyond that of forming a bond of communication between adult and child. It also, he argued, enters into the organisation of the child's voluntary behaviour in the form of self-generated, verbal instructions which in some sense regulate the behaviour.

This chapter begins with a statement of Vygotsky's basic ideas. The development of the theory by A.R. Luria is then examined and some theoretical and experimental objections are considered. Finally a general formulation of Luria's theory is given which provides the focus of subsequent experiments.

**Vygotsky's Theory**

For Vygotsky (and to some extent Luria) the situation which functions as the basic model for self-regulation by speech is quite simply that of behaviour regulation by the speech of others. The regulation of behaviour by speech might be defined by pointing to cases of a parent manipulating the behaviour of a child by speaking to it. Having defined what is meant by 'regulation' the move must then be made from 'other-
regulation' to 'self-regulation'. Since a child obviously has a verbal output as well as a motor output it should be possible to conceive the child providing his own source of instructions. Luria (1961, p. 3) explains Vygotsky's position by referring to a 'process in which functions previously shared between two persons gradually change into the complicated functional systems in the mind which forms the essence of human higher mental activity'.

Some remarks should perhaps be made about Vygotsky's main theoretical move. It consists in trying to understand the workings of a single person by viewing him as an amalgam of two persons. It may be argued that any theory based on such a move will be empty because it is a case of illustrating idem per idem. Clearly there are dangers here, but a simple defence can be constructed by pointing out that many other theories would perish if this objection to Vygotsky's move were sound. For example, Freud analyses the personality in terms which ultimately must be seen as treating the individual as an amalgam of a number of competing individuals each with their own unitary but radically different personalities. Again, the charge of emptiness of just the sort considered here used to be a favourite argument against atomic theories in physics and chemistry (e.g. Stallo, 1881). The theory was said to be devoid of content because it led to an infinite regress. In this last case the very success of atomic
theories permits the conclusion that however sound the criticisms may appear to be, they cannot, when properly understood, really tell against the value of a theory. (For a full discussion of these issues see Bloor, 1970.) It therefore seems perfectly acceptable for a theorist to make precisely the sort of theoretical move that Vygotsky makes.

Given his basic position Vygotsky is able to identify those cases when a child is engaging in self-regulating speech. These are the occasions when the speech is what Piaget (1926) called 'egocentric'. Vygotsky, then, differs from Piaget in the interpretation to be given to the decline of egocentric speech which takes place at about the age of 7. For Vygotsky the decline represents the final internalisation of regulatory speech after its splitting off from social speech. For Piaget this decline is simply the atrophy of unsocialised speech. To support his case Vygotsky points to the changing structure and decreasing intelligibility of egocentric speech as its amount declines. Vygotsky's more direct evidence for the regulatory role of egocentric speech is limited to observations such as that the amount of egocentric speech increases with task difficulty and frustration. These observations are reinforced by anecdotal evidence. For example, it is noted that a young child drawing a car exclaimed "broken" when his crayon broke, and then proceeded to draw a broken car.
Vygotsky contrived an experiment (which he thought was a crucial experiment in Bacon’s sense) to test his theory of egocentric speech against Piaget’s. Briefly, Piaget’s theory can be characterised by imagining the social world and the egocentric involvement of the child as two forces pulling in opposite directions. Limiting the ‘social pull’ by restricting the possibility and appropriateness of communication should increase the pull of the ego and so increase the amount of egocentric speech. Vygotsky’s theory results in the opposite prediction. For Vygotsky the reason why speech-for-self occurs out loud at all is because the child cannot distinguish those situations calling for external speech and those calling for silent speech. Cutting down the possibility of communication should make the discrimination easier, so the amount of egocentric speech should go down. Placing children in a noisy environment or amongst deaf and dumb children reduced egocentric speech to almost zero, as Vygotsky predicted.

As Duhem pointed out long ago (Duhem, 1906) the idea of a crucial experiment is suspect because of the large number of background assumptions underlying any experiment. In this case it is evident what scope there is for alternative explanations of the reduction in egocentric speech in the situations described.

Recent experiments, however, have shown Vygotsky to be superior to Piaget in accounting for data regarding egocentric speech. Kohlberg, Yeager and Hjertholm (1968)
investigated the relation between egocentric speech and intelligence and maturity of interaction with peers. They also looked at the relation between egocentric speech and task difficulty. Vygotsky's theory predicted more private speech (Kohlberg's terminology) amongst brighter than average children at the younger age studied (4 yrs.) and the reverse for older children (6-7 yrs.). Piaget's theory predicts less private speech amongst the brighter children at both ages. The results were as Vygotsky's theory required. With regard to the maturity of interaction with peers (communicative speech and a rating for cooperative attitude were the measures) Piaget's theory would predict that egocentric speech should reflect incapacity or disinterest in social communication. Vygotsky's theory is consistent with a positive correlation between egocentric speech and social speech. The study revealed a positive correlation. It also revealed (in 4½-5 yr. olds) an increase in egocentric speech with task difficulty. To answer the objection that this result could be explained by assuming that egocentric speech was simply an expression of frustration, Kohlberg was able to utilise the following fact: although three tasks evoked egocentric speech in proportion to their 'cognitive' (as distinct from, say, manipulative) difficulty, a fourth 'non-cognitive' task, which was a difficult one, did not evoke much egocentric speech. (The task was building a tower from blocks. Its
difficulty was assessed by the same criterion as the
tasks, namely the number of Ss spontaneously
calling it difficult.)

The situation is, then, that much of Vygotsky's
theory seems to be reasonably substantiated. Before
looking at Luria's elaboration of the Vygotsky picture
it would be appropriate to examine very briefly the way
in which the doctrine of the self-regulating function
of speech has been developed by non-Soviet theorists.
The development of this idea by the early behaviourists
will help to provide a basis against which to judge
Luria's theoretical position.

The early behaviourist Dashiell (1927) referring to
verbal utterances says, "once built up as social stimuli
and responses they become modes of self-stimulation as
well, and the reactions of the individual human organism
come to be directed to some degree by them" (p. 486).
Goss (1961) in his account of the history of the idea of
the verbal mediating response offers a quotation from
Weiss (1929) which illustrates in more detail the
behaviourist idea of self-regulation.

The speech mechanism that produces food
[presumably the word 'food' DBJ thus serves
two purposes: (1) the sound of the word food
may act as a stimulus to prepare the individual
to react.... (2) The sight of any new object
which resembles the edible food objects but for
which the individual has not learned a specific
handling reaction, may release the reaction
food and this in turn the repertory of food
handling sensory-motor mechanisms....

(Weiss, 1929, pp. 318-319)
Language, then, not only functions as a signal of signals but also intervenes to produce responses which, it is claimed, would not have been evoked except by its mediation. The relationship of the above to the basic Vygotsky model can be seen by the fact that the first purpose served by language on Weiss' account deals with the case of a person hearing the word 'food' from another, whereas the second case is that of someone eliciting motor responses from themselves by virtue of their having uttered a word. Despite the similarity with Vygotsky's picture it will become clear that the early behaviourist account differs from that developed by Luria. Luria has attempted to spell out the details of the relationship between speech and motor responses in young children in such a way as to both extend the scope of Vygotsky's ideas and to put them on a firmer experimental footing. In speculating about the possible mechanisms at work he has appealed both to neo-Pavlovian concepts and also to the notion of 'feedback' from cybernetics.

Luria's Development of Vygotsky's Theory

A central theoretical point in any scheme such as Vygotsky's is that if the speech system is to regulate the motor responses in such a way as to permit them to achieve a level of performance of which they would be incapable on their own, then the disorganisation present in the motor system must not be present in the system.
doing the regulating. Let this condition be called 'The Vygotsky Condition'. Luria has made a number of experimental claims which can be seen as furthering the task of showing that, and why, the Vygotsky Condition is indeed fulfilled. For example he claims that in 3 to 4 year old children the ability to give verbal responses, such as saying 'go', to sequences of blue light signals, whilst inhibiting this response for interspersed yellow signals, is greater than the ability to perform the corresponding motor task where the response is pressing a small rubber bulb (1961, p. 45). Luria then attempted to use the "more perfect neurodynamics and greater controllability" of the verbal system to regulate the motor responses. Such a process of regulation is said to take place when a child of this age performs both the verbal task and the motor task at the same time. The result, according to Luria, is that the motor response improves as a result of being accompanied by the verbal response (1961, p. 46). It is not, however, the meaning of the word 'go' or 'press' or whatever is uttered, which exercises a controlling function over behaviour. The control at this stage is held to be grounded in the physiological excitation underpinning the verbal response. One immediate result of the non-specific nature of the controlling influence is that to say 'don't press' has the same impelling result as to say 'press', in that it provokes a motor response. Luria claims that this deduction is supported experimentally (1961, pp. 57-8).
Only at a later stage does verbal regulation utilise the semantic rather than the impulsive aspects of speech (this part of Luria's theory will be elaborated at the end of the chapter).

How does Luria conceive of this process of very basic regulation working? The answer is to be found in what he offers as "the first and simplest model of a voluntary movement in a very young child" (1961, p. 38, Luria's underlining). This model consists in an experimental situation just like those discussed above where a child makes a motor response to a sequence of stimuli, except that when the child makes the response he receives distinct exteroceptive feedback - say from a buzzer - which functions as an external sanctioning signal.

Luria accounts for the relatively poor performance of young Ss on the motor, as distinct from the verbal, task by suggesting that the proprioceptive feedback from the muscles of the hand is inadequate for the purposes of fine control. Luria therefore introduced the exteroceptive feedback to ensure that the feedback loop was completed. The results of experiments attributed to S.V. Yakovleva are reported in which, for example, 75% of children aged 2-3 years showed a complete disappearance of intersignal pressure and clear cut, well co-ordinated reactions to a sequence of signals (there were no signals which required an inhibition of response in the experiment reported). Removal of the
feedback led to a decline in performance. The introduction of feedback thus has marked effect, and this is crucial to the development of Luria's argument. The next step in this argument is to say:

the most essential and fundamental fact, characteristic of this stage (3-4 yrs. DB) of the child's development, is that similar results can be obtained if we replace the external sanctioning afferentation by the child's own speech... we replace the regulatory action of the external signal by the child's own verbal commands, which, owing to its more perfect neurodynamics and greater controllability, now becomes a good regulating mechanism.

(Luria, 1961, p. 46, Luria's underlining)

In summary, Luria's argument is in two parts: (1) feedback greatly improves performance; (2) the feedback effect can be taken over by the child's own voice. The role of speech is to be understood by modelling it on the feedback experiment. The voice makes man into a cybernetic system, a self-regulating mechanism, to use Pavlov's famous phrase which Luria quotes.

Although Luria leaves his readers in no doubt that the external feedback arrangement is to provide a model for understanding the regulatory function of speech, a certain amount of obscurity still lingers. After all, the exteroceptive feedback is consequent upon the motor response being made, and it has its source outside the person responding, whereas the voice seems to be a system which is working in parallel with the motor response, and is coming out of the person in the same way as is the motor response. These difficulties may
ST  \textsc{exterceptive-}\textsc{feedfeedback}\textsc{loop}

(a) THE BUZZER EXPERIMENT

(b) THE MODEL

LURIA’S FEEDBACK MODEL OF VERBAL SELF-REGULATION

FIG. 1
be examined in more detail by appeal to pictures of what is happening within the responding person. Consider the schematic and hypothetical arrangement of Fig. 1.

Fig. 1(a) is the case where poor proprioceptive feedback is replaced by good exteroceptive feedback. Fig. 1(b) is the case, requiring clarification, of the verbal system apparently playing an equivalent role. Assume, for the sake of the argument, that the motor decision mechanism (M) can link itself to the verbal decision mechanism (V) in a completely mechanical manner (like the response bulb and the buzzer) so that a 'decision' of M's becomes a 'decision' of V's. In this case the exteroceptive feedback from the voice will be reliably linked with a motor decision, just as the sound of the buzzer was; so the feedback loop will be closed in a manner closely resembling the model.

Even now, though, not all the obscurities have been cleared up because a number of questions of detail can be raised. It has been assumed that M (the motor system) can form links with V (the verbal system). Unless this is going to be a completely arbitrary stipulation there must be a general rule to the effect that decision mechanisms can link themselves together. But in this case surely V (the verbal system) could link itself to M (the motor system), so that another arrow must be added to the diagram, this time going from V to M. If this were the case there would be an internal feedback loop, and the completed loop would not need to have an
As soon as the Vygotsky Condition was satisfied (that is, the speech system is adequately developed) it would be ready to work implicitly without any exteroceptive component at all. This would run counter to Luria's position in two ways. First, Luria has always stressed the spoken and explicit responses of the verbal system. He would insist, as Vygotsky insisted, on the necessity of a function developing explicitly and publicly before it can develop implicitly and privately. The idea of implicit speech (i.e. the internal speech 'decision' without its motor component) having a function which has not evolved from a public function would be unacceptable; so the exteroceptive loop cannot be dispensed with right from the start. Secondly, Luria has remarked upon the fact that getting a child to whisper, and so cutting down the exteroceptive feedback, destroys the regulatory function of speech. The analogy with the buzzer experiment would point to this conclusion, but what is emerging is the difficulty of squaring this superficial similarity with the details of the diagram (b).

The problem, then, is that either a one-way link from M to V must be assumed, which is arbitrary, or else a two-way link must be assumed, which seems to dispense with the need for exteroceptive feedback, which means that the theory contradicts the model of which it was supposed to be an elaboration.

There is difficulty, then, in making clear what has
been called premise (2) of Luria's argument: that the feedback effect is taken over by the child's voice. But purely theoretical objections may be limited by suppressed premises and assumptions, and looked at from another perspective the difficulties may disappear. What is required is an experimental examination of premise (1) to see if feedback really does improve motor performance. If it does not have this effect then the question does not even arise of whether external feedback can provide a model for the regulatory function of language. The first experiment will check up on these facts.

An early version of Luria's theory is described in his book The Nature of Human Conflicts (Luria, 1932). A look at this detailed account will help to fill out the picture that Luria is proposing.* Here (especially

* In the earlier chapters of his 1932 book Luria developed an objective technique for the study of the emotions. He used a word association test in conjunction with a simple motor response from one hand and a measure of tremor from the other. He argued that the kymograph trace of the motor response reveals the details of the central associative processes, for example the development of affect or the inhibition of a verbal response. The cooperation of the Soviet police in providing Luria with criminals as experimental subjects make it tempting to think that he was in fact trying to develop a 'lie-detector'. Runkel (1936) performs an amusing experiment in which the Luria technique is used for this purpose, with a certain degree of success. The clinical, though not the forensic, potentialities of Luria's method have attracted some Western workers who have "shown the essential correctness of Luria's thesis" (Clarke, 1955), whose paper, along with Morgan and Ojemann (1942), provides references to this work). The present study will not concern itself with the role of emotion as a source of motor disorganisation, except indirectly at one point via the concept of 'arousal'. Later discussions of arousal, e.g. Duffy (1957) and Malmo (1957), in effect developed a theme of Luria's which he first investigated some twenty years earlier.
in Chaps. 10 and 11) Luria was already working with children and using an experimental arrangement similar to that described earlier, i.e. Ss pressed a rubber bulb in response to a sequence of light signals. By this time he had also developed the thesis that language exerts a regulatory function, but he used the analogy of a 'shunting' process to illustrate the relation between the two signal systems (1932, p. 421). Luria here may be referring to a 'shunt' in an electric circuit which is often fitted across a galvanometer and is simply a piece of low resistance wire designed to carry most of the current so that the instrument is not damaged. It is a matter of conjecture whether it was explicitly the electrical analogy that Luria had in mind, but quotations will show this accords well with the imagery he uses. The way that this analogy fits into his thinking will now be examined.

The motor system in a child is characterised, up to the age of about 6, by a 'diffuseness' which Luria pictures as an uncontrolled spreading of excitation in the brain. In other words, a stimulus does not function selectively in triggering just this response but not that. Further, a response cannot easily be delayed or produced in a standard form to signals of varying length or intensity. With training and growth these deficits are overcome but the path taken to achieve greater control and organisation is viewed by Luria in a novel way. It is not achieved by means of the gradual accumulation of
well-conditioned S-R connections (growth from below, as Luria calls it) but rather by the intervention of higher cortical processes. The intervention of these higher processes with their 'intricate and labile system of making connections' (1932, p. 349) permits the development of what Luria calls a 'functional barrier' between the stimulus input and the motor decision mechanism. This functional barrier prevents the 'overloading' of the motor system and is responsible for the 'shunting' of the excitation into the verbal system. This Shunt Model, as it will be called, is captured in the following quotations:

The explanation of the structure of the reactive process brings us to a scheme differing somewhat from the usual, the scheme of the reactive arc. The given stimulus evokes in the system a certain excitation; reaching the central apparatus, it, however, is not connected directly to the motor system, but is restrained by some 'functional barrier', and after the definite preliminary elaboration as a result of which there comes about a linking-up to the motor system, and the motor reactions do not show traces of that 'overloading' characteristic of the preliminary central process.

(Luria, 1932, p. 349)

We come to the conclusion that between the stimulus and the reaction in the adult lies a certain regulating mechanism which causes a corresponding transfer of excitation to the motor path, but does not admit to the motor system the whole quantity of excitation which was produced by the stimulus.

(Luria, 1932, p. 342)

This account is illustrated in Fig. 2 (a) and (b).

Although this picture is still vague it does not
suffer from the initial difficulties associated with the Feedback Model. It does, though, depend crucially on the Vygotsky Condition, which here takes the form that the verbal system, because it can act as a shunt bearing the bulk of the excitation produced by a stimulus, must be better organised (less 'diffuse') than the motor system.

So far two rather different accounts of the details of the process of verbal self-regulation have been presented, which have been labelled the Feedback and Shunt Models respectively. It may be thought that the existence of two models reveals an inconsistency in Luria's theory. Perhaps the best response to this situation is to see both models as tentative articulations of an overall approach which is capable of being extended in a variety of directions. The ideas so far discussed can be arranged in a hierarchy. At the top, on the most general level, comes Vygotsky's thesis. This sees language as being the means whereby problem situations are analysed and courses of action elaborated. Language serves the function of steering behaviour.

Luria's work comes on a lower level of generality. He is trying to press Vygotsky's thesis of verbal regulation into service in explaining the execution of the tasks already set for behaviour. This second level of generality emerges in the claim that language is involved in the organisation of ongoing motor responses. Much of what Luria says consists of claims on this level of
16.

**AN ELECTRICAL SHUNT**

**LURIA'S SHUNT MODEL OF VERBAL SELF-REGULATION**

**FIG. 2**
generality; and more will be said about these formula-
tions at the end of this chapter. The third and lowest
level in the hierarchy consists in specific claims about
the details of the processes postulated above, and it is
here that the two models are encountered.

Two Criticisms

Before passing on to the experimental part of the
study there are two outstanding points to be dealt with.
The first point is that the Vygotsky-Luria picture of
language has already been subjected to an experimental
attack (Jarvis, 1963) and the results require comment.
Next, there is a quite general argument due to Broadbent
(1958) which may be thought to rule out a priori anything
even resembling the Vygotsky-Luria theory, and this
clearly requires examination. First the theoretical
point will be considered and then the experimental one.

(a) The Broadbent Objection

In considering the relation between verbal and
bodily responses (p. 47) Broadbent remarks on the
different capacities of men and animals to perform pre-
determined sequences of actions. For example, monkeys
find it very difficult to solve problems that require
them to learn to perform a sequence of responses in a
certain order. The superiority of man in this respect,
says Broadbent, is often attributed to the use of
language, because men appear to solve such problems by
formulating a rule and using it to guide their actions —
and this, of course, is the thesis that language has a regulatory function. In Broadbent's view such an explanation puts the cart before the horse. It is not that we can solve problems of this sort because we have language, he argues, but because we have large enough nervous systems, and this in turn is why we possess language.

This argument was not directed explicitly against Vygotsky or Luria, its target was probably the early behaviourists, but clearly a cogent point has been made which requires answering. The force of Broadbent's point can be best seen in connection with the quotation from Wiess given earlier. Broadbent would want to ask Wiess why the verbal system can engage in processes of classification and decision which the motor system cannot. The verbal response presupposes a certain capacity for processing information, so the behaviour has not been explained until the possibility of the verbal response has been accounted for. For theorists such as Wiess and Dashiell working with a S-R theory the problem is particularly acute because the principles of learning are identical for both language and motor responses. A stimulus which is sufficiently different from previous food stimuli should no more evoke the word 'food' than it should food handling responses. For Vygotsky and Luria the problem is not quite so great. To begin with they would be less inclined to insist that the same principles of learning are at work for all
different types of response* and in any case there is a tendency to see the responses coming from two different systems which are quantitatively, even if not qualitatively, different. This allows a means of escape from Broadbent's point because there is no reason a priori why the greater resources of our larger nervous systems (compared with other animals) should not be invested differentially in favour of the language system, and then be exploited by giving language a regulatory function.

(b) A Failure to Replicate Luria's Results

Assuming now that the Vygotsky-Luria thesis can get off the ground at all, the experimental attack will be considered. This consists in the failure of P.E. Jarvis to replicate one of Luria's experimental claims. Jarvis conducted a thorough investigation to see if there is 'a stage of development during which instructing the child to verbalise...to give himself instructions...whilst performing a sensory-motor task will improve his performance if he tells himself what to do, but hinder his performance if he tells himself what not to do'.

The task involved pressing a button with the thumb when a blue light appeared. There were three experimental conditions: (i) a silent condition, (ii) a push condition, in which Ss said 'push' when they saw a blue light and pushed, (iii) a don't push condition in which

* This point is discussed more fully when the general form of Luria's theory is elaborated at the end of the chapter.
Ss said 'don't push' whenever they saw a yellow light. Jarvis' results did not support Luria's hypothesis. They showed that the child's ability to perform the task improved with age, but verbalisation, or the lack of it, had no significant effect on their performance.

This is obviously an important result with potentially devastating implications for Luria's scheme of ideas. Three points about the experiment ought to be borne in mind, however. The first point concerns the extent to which the results are directly comparable. As Jarvis himself pointed out it is very difficult to know exactly what Luria and his co-worker actually did, in detail, in performing their experiments. Although some astute detective work on Jarvis' part enabled him to make a good guess at the speed of presentation of the stimuli, questions about amount of practice, length of trials and, of course, more subtle features about the interaction of the experimenter and the child subject, were all unknowns.

The second point is that there is an important feature of Jarvis' experiment about which he gives no objective information. This concerns the actual verbal behaviour of the children during the performance of the experimental task. The children in two of the groups had to utter the word 'push' or the words 'don't push' very frequently throughout the task. There is no data given as to whether they actually did this, or, if they did, whether they said it aloud or whether they
whispered. It might appear that it can be taken for granted that the children would say this completely unselfconsciously and in their normal speaking voice. The present writer's experience is that it cannot be taken for granted; such a repeated verbal response has a tendency to die away into a whisper, and certain children are very self-conscious about mouthing things aloud in such a curious situation. It is not revealed, for example, if any Ss were rejected because of inhibition of the verbal part of their response. If it is supposed, perhaps quite unjustly to Jarvis, that his Ss tended to whisper then Luria could argue that we might indeed expect the result that verbalising or not verbalising made no difference.*

The third, and final point about this important experiment is that it is necessary to realise the scope of the result, even if it is taken, as perhaps it ought to be, as a direct refutation of one of Luria's specific claims. Whilst Jarvis' finding may be the end of some of Luria's picture of language-motor interaction in child development, it does not demolish the less detailed and less tightly-knit framework of Vygotsky's ideas within which Luria worked. The particular experimental results which Luria offers as an exemplification of language regulating behaviour must perhaps be relinquished, but this does not mean that the general

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* Experiment 3 of this study, however, constitutes a measure of defence for Jarvis against such a line of argument.
idea of language in some ways and in some circumstances having a regulatory function must be discarded. Nor, of course, does it demolish the recommendation that, if such a regulatory function be found, it is to be understood in terms of the alleged result of introducing exteroceptive feedback. The form of language regulation and interaction with other systems may be more subtle than to reveal itself in the situations specified by Luria and checked by Jarvis. An example of more subtle modes of interaction is provided by the experiment of Corcoran (1966). He found that in a task requiring Sa to cross out 'e's as rapidly as possible in a printed passage, there was a tendency to miss 'e's which would have been silent had the passage been read aloud. Here it looks as if the spanning of the acoustic image of the word is more efficient than, or perhaps merely predominates over, the result of scanning the visual image. Alternatively, as Corcoran himself concludes, the response of crossing out the letter was perhaps facilitated by the coincidence of the outputs of the visual and acoustic scanning. Again, there are results such as Fletcher's (1962) which point to further kinds of verbal-motor interactions. He found that the two-choice reaction time of 6 year olds was significantly decreased if the lifting of the response key is accompanied by a spoken 'go'. The accompanying verbal response, however, was found to increase the two-choice reaction time of young adults.
Jarvis' results, though, naturally throw doubt onto the more elementary experiments of Luria's which led up to the one which he tested. These are the very results which Luria presents as showing that the Vygotsky Condition is fulfilled and that feedback has a significant effect. It will be these elementary experimental claims that will now be examined. The focus will then pass on to attempts to find more general experimental tests for the presence of Luria-like links between speech and action.

EXPERIMENT 1. AUDITORY FEEDBACK AND MOTOR PERFORMANCE IN 4 AND 5 YEAR OLDS

In this section an account will be given of an attempt to repeat one of Luria's experiments under clearly stated and appropriately controlled conditions. The hypothesis tested can be stated as:

Hypothesis

The ability of young children to perform the motor task of pressing a rubber bulb to blue light signals but not to yellow light signals is improved by the introduction of auditory feedback produced by the response.

The role of this experiment in Luria's scheme is that (1) it is held to support the idea that the relative inadequacy of the motor system is due to insufficient proprioceptive feedback, and (2) it provides a model in terms of which the role of language
can be understood.

The hypothesis is not stated in fully operational terms. This would be tedious to do explicitly, but will be done implicitly in the following manner.

'Young children' is defined in Table 1 where the $S$s are described. The word 'ability' will be defined in terms of the number of errors of the different types given in the section on scoring criteria. The term 'improved' also requires definition. The meaning most appropriate to Luria's intention is that if $F$ is the population of scores of those $S$s given feedback, representing the number of mistakes they have made, and $NF$ is the corresponding population of scores for the $S$s not given feedback, then $NF$ is stochastically larger than $F$, or the bulk of $NF$ is higher than the bulk of $F$ (Siegel, 1956, p. 116). The vague specification of the stimuli and feedback will be refined in the sections giving details of the apparatus.

Subjects

The 64 $S$s were from two local authority schools, the Moray House Demonstration School, Edinburgh, and the Drummond Street Primary School, Edinburgh. The schools were selected because they were situated near the University. The $S$s were divided into two groups according to age. The older group were drawn from the infant school classes at the two schools mentioned, the younger group from the nursery classes of the Drummond
Street School. The two groups (N = 32) had equal numbers of boys and girls. The mean age for the two groups is given in Table 1. No investigation into educational level or wealth of parents was conducted though there is no reason to think that constitution of the two age groups differed significantly in this respect. The two schools did not differ in classroom organisation, both adopted a free regime called 'the integrated day', with the children working in small groups. The experiments were carried out during the schoolday without parents being present.

No Ss had to be eliminated because of sensory-motor defects, nor were any Ss known to the teacher to be colour-blind (visiting school doctors would have informed the teachers had any child been colour-blind). One older child was eliminated from the experiment through unwillingness to perform the experiment; also eliminated were two of the younger children who were reluctant to leave their playmates and two who were unwilling to perform the experiment. These five are not counted in the 64 mentioned above.

All Ss were of normal intelligence. A few days after they had been given the experimental task they were given a modified form of the Peabody Picture Vocabulary Test. The minor modifications were to eliminate specifically American words. Details of the modification are given in Appendix I. Since the test has not been standardised for Britain the mean raw score
is given in Table 1. The test was used in preference to established I.Q. tests because of the ease and rapidity of application.

### Table 1
#### Details of the Subjects of Experiment 1

<table>
<thead>
<tr>
<th>Subject Group</th>
<th>Number</th>
<th>Mean Age in Months</th>
<th>S.D.</th>
<th>Mean Peabody Test Scores*</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Ss (Nursery)</td>
<td>32</td>
<td>51.6</td>
<td>7.9</td>
<td>46.5</td>
<td>12.1</td>
</tr>
<tr>
<td>Older Ss (Infant School)</td>
<td>32</td>
<td>69.3</td>
<td>3.7</td>
<td>59.1</td>
<td>11.1</td>
</tr>
</tbody>
</table>

* Raw Score. See Appendix I.

### Apparatus

The apparatus was designed to provide the Ss with a Luria-like situation but was to have the refinements of uniform and repeatable stimulus presentation and automatic and graphic recording of results, as with Jarvis' later experiments.

The specifications of the stimulus unit were as follows: this was to produce flashes of light 0.5 secs. long on two bulbs in an order which could be specified before the experiment began and reproduced when required. The inter-stimulus interval was to be 0.75 secs. These values were chosen to correspond to those used by Jarvis, which were in turn chosen to approximate to those used by Luria as judged by an examination of reproductions of
kymograph tracings in published papers. Each flash was to be recorded on an event recorder. The experimental run was to consist of 50 flashes, 30 of these were to be blue (requiring a response) and 20 were to be yellow (requiring no response). These ratios were taken from Jarvis. The exact stimulus pattern, which is meant to be random, is given below.

Letting a plus sign indicate a blue light and a negative sign indicate a yellow light the stimulus sequence was:

```
+ + + + - - + + + + + + - -
+ - - + + + + + - + + - +
+ + + - - + - + + - + + - -
```

**Stimulus Sequence for Exp. 1**

The stimulus bulbs (ordinary torch bulbs) were mounted in a 22" by 22" vertical screen in such a way as to illuminate from behind the eyes of a cartoon rabbit figure drawn onto the screen. The 'eyes' were 3" diameter commercial warning lights made of plastic. The blue light on the right, the yellow on the left. The lights had their centres 14" apart. The apparatus was such that the lights could be switched on and off manually so that the task could be demonstrated to the Ss.

The lights were actuated by pulses fed from a portable UHER tape-recorder, one channel per light. The pulses, which were put onto the tape by means of a computer, also triggered the event recorder. Pressure from the 1½" diameter response bulb was fed into a
pressure transducer (Penny and Giles, type T.P.8) and in turn into the event recorder and loudspeaker to provide a buzzing noise to act as auditory feedback. The apparatus is presented schematically in Fig. 3.

For the purposes of the experiment the apparatus was placed in an empty classroom which was sufficiently far from the others to be free from distracting noise. The transducer, buzzer, low voltage power supply and control box were packed behind the stimulus screen out of the view of Ss. The tape-recorder and event recorder were separate behind either a screen or movable blackboard at the side of the room. The stimulus screen was placed on a small table in front of which the Ss sat holding the response bulb whose connecting tube emerged from the bottom of the screen.

**Experimental Design**

Each S was given instructions and training up to a specified criterion, and then two experimental runs. The task assigned to S was to press a rubber bulb held in the hand when he saw a blue light but to refrain from pressing it when he saw a yellow light. On the second of the runs some Ss were given auditory feedback from their responses in the form of a buzz produced by pressure on the bulb. Equal numbers of Ss from each of the two age groups were used, and half were assigned to the feedback (F) group, and half to the non-feedback (NF) group. Both F and NF groups contained equal
APPARATUS FOR EXPERIMENT 1

FIG. 3
numbers of boys and girls. Both groups had brief practice between the two experimental runs, which took the form of one run up to the criterion. This was mainly for the benefit of the F group to accustom them to the presence of the buzz, but was given to the NF group to control for amount of practice. This design permits comparison of the relative improvement over two runs of the Ss with and without feedback. The hypothesis tested predicts that Ss with feedback will improve more than Ss without feedback.

Procedure
(1) Introduction of S to experimental situation.

The older Ss were introduced to E in the school classroom by the teacher who explained that E had an interesting game that they might want to play. In both schools children volunteered instantly to accompany E. With the younger nursery children, E made himself a familiar figure in the playroom by a number of preliminary informal visits. The children were then approached to act as Ss through the teacher. Again many children volunteered as soon as they knew what was wanted.

The Ss were then taken by E to the classroom containing the apparatus and seated in front of the stimulus screen. The rabbit figure was indicated and the children were asked what it was. Most of them replied 'rabbit', or 'bunny', though some called it a
dog. The label volunteered by $S$ was then used by $E$ who explained that the figure had funny eyes which winked: the blue and yellow lights were then operated manually to show this. $S$ was then asked to name the colours of the lights when they were presented. Throughout the experiment $E$ used the colour labels volunteered by $S$ in the few cases where blue was called black, or where yellow was called orange. Where $S_a$ occasionally did not know the colour word they wanted to use, colour labels were dropped by $E$ and the lights simply indicated by touching them. Even when colour labels were used by $E$ the use of the colour word was always accompanied by pointing carefully at the relevant light.

(2) Instructions and Training.

It was explained to $S$ that the game was to take hold of the rubber bulb (which was called a 'squeezer') and give it a hard squeeze every time the rabbit winked with the blue eye. (The bulb was to be held in the child's preferred hand.) The instructions proceeded, 'Sometimes the bunny will wink with the blue eye (point at blue eye) and sometimes he will wink with the yellow eye (point), when he winks with the blue eye I want you to press like this....' A sequence of blue flashes were given with the $E$ holding the bulb near the rabbit's face and very obviously squeezing the bulb. The bulb was held near the rabbit's face so that both would be in the child's field of vision. If $S$ had had to look back
and forth at the lights and the E's hand this may have resulted in missing some of the flashes and the correspondence between presses and flashes. Then a mixture of blue and yellow lights were given with E stressing that no squeeze was to be given for the yellow light.

The child was then given the bulb and was able to practise the task. Ss were also asked before they began practising on their own to tell E what they were to do. If S could not formulate the instructions, as many of the younger ones could not, then they were prompted, 'What do you do when this one (pointing), the blue one, comes on?' All Ss were capable of saying 'press' or 'squeeze', and 'don't press' to the further question concerning the yellow light.

Throughout the training period E maintained an encouraging but unhurried manner with plenty of 'reinforcement' for successful mastery of the different phases of the task. The Ss invariably found that they were making mistakes, usually of the form of pressing for the yellow light, and were often amused at being caught out.

During the training E presented the lights manually. Training continued until Ss had reached a criterion, which was to perform faultlessly the sequence, 

\[+-+-++--\]

where + indicates a blue light and a press, - indicates a yellow light and no press. Each signal and each gap between signals lasted about one second in this test.
(3) The Experimental Runs.

The Ss were then told that they would now have the winking eyes put on and off, not by E, but by a machine that would do the job for him so that E would not get tired. S was to look at the eyes very carefully and remember what he had to do. E then left the chair by the side of S and switched on the event recorder, which made a slight buzz. E told S that this meant the lights were going to come on so he must look at the rabbit. When S was looking at the stimulus screen E switched on the tape recorder which actuated the lights. E then quietly returned to his chair looking at the lights not at E in case this would distract him. E said 'good' quietly as he sat down to encourage S. If S turned to E during the experiment, he was gently reminded to look at the eyes and remember what he had to do; E would himself be looking at the lights not at E whilst saying this.

It was decided to adopt the policy of being seated beside the S for three reasons. Firstly to construct and transport a cubicle for use by S would be costly and difficult. Secondly it is not clear that any increase in objectivity is obtained by placing Ss in a situation which may, rightly, arouse their suspicions; they may spend more time thinking about why they have been isolated and when the isolation will finish than about the task. Thirdly the experimental situation adopted permits Ss to receive generalized encouragement from E in a natural way.
Between the two runs the NF group received a brief practice run using the test sequence mentioned above. The F group were shown how the pressing of the bulb now caused a buzzer to sound.

Each experimental run lasted about two minutes. The total time S was with E varied depending on how rapidly the task was mastered. Total time was not recorded but was in the region of ten minutes. S was then taken by E back to classroom.

Scoring Criteria

As with the stimulus values, the method of scoring the Ss' performances will be taken from Jarvis, though slight refinements to his criteria will be mentioned.

A response will be defined for the purposes of this experiment as pressure on the bulb by the S sufficient to trigger the event recorder. Only an on/off measure was used.

The following five categories into which the responses fell will be quoted directly from Jarvis since he adopted an obvious and logical classification. A blue flash is referred to as a positive stimulus, a yellow flash is referred to as a negative stimulus.

(1) A missing response (M) was scored whenever S failed to make a response to a positive stimulus before the onset of the next stimulus, whether positive or negative.

(2) A response to a negative stimulus (N) was
scored for the first response made in the time between the onset of the negative stimulus and the onset of the next stimulus.

(3) A late response (L) was scored for the first response which began between the termination of the positive stimulus and the onset of the next stimulus. If more than one response was made during this period, only the first was scored L.

(4) An extra response (E) was scored whenever there was more than one response made between the onset of one stimulus and the onset of the next stimulus, all responses after the first one during any such period being scored E.

(5) All other responses were considered correct responses (C).

Although the above categories were used for classifying responses it was decided to supplement the comparison of Ss purely in terms of the number of late responses made. The reason for this is that the number of late responses alone is not necessarily directly indicative of the level of performance. This is because both very good and very bad performers could have a lower L score than a mediocre performer. The bad performer will have a low L score because has made very few responses at all, and the good performer because his high number of responses were made rapidly. For this reason the L score alone, unlike the other
categories, was not felt to be adequate. Instead, the ratio of late to correct plus late scores, $L/(L+C)$, was used.

Occasionally the response trace showed a response which appeared to begin in exact alignment with either the end or the beginning of the trace indicating a stimulus. In this case Jarvis' definitions above were modified to the following which give an unambiguous decision for all responses.

(i) A response which begins exactly at the end of a positive stimulus is counted $L$.

(ii) A response which begins exactly at the beginning of a positive or a negative stimulus is assumed to be a response to the previous stimulus, i.e. is $L$ or $N$, or is $E$, whichever is appropriate. The justification for this is that zero reaction times are not acceptable, though for simplicity the convention was adopted that all other reaction times however short were acceptable.

Results

Non-parametric statistics will be used throughout. A sufficient condition for using non-parametric rather than parametric statistics is that important assumptions for the use of the latter are violated. Two such important assumptions are that the observations be drawn from normally distributed populations and that the
variances of these populations is the same, or, at least of a known ratio. In the case of the data to be dealt with, the distributions depart greatly from normality; further, there is no guarantee that the variances of the populations involved are equal. For example, for missing responses, if we consider the variances of the improvements over two runs for the feedback (F) and non-feedback (NF) groups we can reject the hypothesis that the variances of the populations from which the samples were drawn do not differ at the 0.01 level of significance \( F = 2.6 \) with 31 and 31 df, \( p < 0.02 \). Further, there is no a priori reason for assuming any particular ratio of variances.

The experimental results will be presented in the following order: (i) analysis of missing responses, M, (ii) analysis of responses to negative stimuli, N, (iii) analysis of the proportion of late responses to the total number of correct and late responses, \( L/(C+L) \), (iv) analysis of the number of extra responses, E. For each score the most important feature will be the relative improvement over two runs of the F and NF groups.

**Missing Responses**

(1) First: the performance of Ss as measured by the number of missing responses on their first exposure to the task will be examined. Luria's work, in conformity with general expectation, predicts that the level of performance is higher for older Ss. This is,
in fact, the case. On a Mann-Whitney U test the difference is significant at the 0.01 level on a one-tailed test. The first runs of both the F and NF groups are considered together in this case giving a calculated value of U with $p < .01$ on a one-tailed test with $n_l = n_2 = 32$.

(2) Male and female Ss will now be compared, dealing with the two age groups separately and combining the first runs of the F and NF groups. Using a Mann-Whitney test the comparison of male and female Ss yields $U = 127.5$ for the younger group, and $U = 122$ for the older group. For $n_l = n_2 = 16$, on a two-tailed test these are not significant at the .05 level. So male and female Ss do not differ.

(3) The next question regarding the first run is whether the random division of Ss into experimental (F) and control (NF) groups has indeed produced groups which, on the first run, are comparable in performance.

Taking the younger Ss first: comparing the first runs of the male and female Ss separately in the F and NF groups in neither case does the calculated U in a Mann-Whitney test have a probability less than $p = 0.44$ under Ho on a two-tailed test. (Male Ss, $U = 31.5$, $p < .96$; female Ss, $U = 25$, $p < .44$; for $n_l = n_2 = 8$, on a two-tailed test.) So young experimental and control Ss do not differ, significantly, at the 0.05 level in their first run.

Looking at the older Ss and comparing male and
female Ss separately in the experimental (F) and control (NF) groups, in neither case does the probability of the calculated U have a value less than .16 under Ho on a two-tailed test. (Male, U = 26.5, p < .95; female, U = 18, p < .16; for n1 = n2 = 8, on a two-tailed test.) So the older experimental and control groups do not differ significantly at the 0.05 level.

So far the male and female Ss have been kept separate. They could be combined and the first runs of the whole of the F and NF groups checked against one another to ensure that they do not differ significantly. This will only be done if the differences between the F and NF groups is in the same direction for male and female Ss: for only in this situation might the combined groups be significantly different whilst the subgroups are not. In the present case of missing responses the difference between the F and NF groups is in the same direction for both the male and female younger Ss. The overall groups, however, are still comparable (the calculated value of U = 106.5 which is not significant on a two-tailed test at the 0.05 level with n1 = n2 = 16).

(4) Improvement over two runs, M score

The first and most noticeable feature of the relationship between the first and second runs of Ss from both the F and the NF groups is how frequently there is a decline in performance. For example, 16/32 of the NF Ss get worse on the second run, as did 12/32
of the $P$ group. Although this is an elementary and obvious fact it is not one which Luria remarks on. It is in itself sufficient to show that whatever the relation between feedback and performance in this motor task, feedback is unlikely to have a dramatic improving effect, even if it has a statistically significant one.

Figs. 4 and 5 show the mean improvement over two runs for the eight different conditions arising from the two age groups, the two experimental conditions, and the division into male and female $S$s. Inspection of the graph shows that feedback seems to have an overall effect on both the young and the old male $S$s, and on the older females, but not on the younger female $S$s. A further point the graphs reveal is that the overall improvement of the older male and female groups is very similar in the absence of feedback.

The table below, Table 2, gives the results of Mann-Whitney tests on the various categories of $S$s.
Improvement over two runs in missing responses

**Fig. 4**

Improvement over two runs in missing responses

**Fig. 5**
(5) The next question to ask concerns the relationship between improvement over the two runs and the initial level of performance, and the way that feedback affects this relationship. The information about this relationship for missing responses is given in Figs. 6 and 7. There is a striking contrast between the F and NF groups.
RELATION BETWEEN IMPROVEMENT IN THE NUMBER OF MISSING RESPONSES AND THE INITIAL LEVEL OF PERFORMANCE (YOUNGER Ss)

FIG. 6
RELATION BETWEEN IMPROVEMENT IN THE NUMBER OF MISSING RESPONSES AND THE INITIAL LEVEL OF PERFORMANCE (OLDER Ss)

FIG. 7
for the older Ss. There is no discernible relation between initial level of performance and improvement for the control groups without feedback, but there is a clear proportionality between number of mistakes made on the first run and amount of improvement for the experimental group. (For the NF group, treating males and females together, the relation between the initial number of mistakes and improvement yields a Spearman Rank Correlation Coefficient of $r_s = .2$ which is well short of significance even at the .1 level on a two-tailed test.* For the F group, again with males and females treated together, $r_s = .9$ which is significant at the .02 level on a two-tailed test.) For the younger group the difference between the F and NF group is less striking but of the same form as for the older Ss. (For the NF group, combining male and female Ss $r_s = .3$ which is not significant. For the F group $r_s = .7$ which is significant at the .02 level on a two-tailed test.)

**Responses to Negative Stimuli**

The approach to the analysis of responses to negative stimuli will be the same as the approach to the analysis of the missing responses. This form will be adopted for all the remaining measures of performance.

* The normal symbol for Spearman’s Correlation Coefficient is rho, but here Siegal’s practice will be followed (Siegal, 1956).
(1) Combining the F and NF groups together there is no significant difference between younger and older Ss with respect to the number of responses to negative stimuli on the first run. (On a Mann-Whitney test the probability of the calculated U is \( p < .33 \) on a one-tailed test with \( n_1 = n_2 = 32 \), corrected for ties.)

(2) Looking at male and female Ss separately for the two age groups there is no evidence that the sexes perform differently. (For younger Ss \( U = 119 \), for older Ss \( U = 105 \), which are not significant at the .05 level on a two-tailed test with \( n_1 = n_2 = 16 \).)

(3) Finally the first run must be examined to ensure that the division of Ss into F and NF groups is unbiased.

Taking the younger Ss first and looking at the male and female groups separately in neither case does the calculated U on a Mann-Whitney test have a probability less than .87 under \( H_0 \) on a two-tailed test. (Male Ss, \( U = 30 \), \( p < .87 \); female Ss, \( U = 31 \), \( p < .96 \) for \( n_1 = n_2 = 8 \) on a two-tailed test.)

For the older Ss comparing male and female groups separately in no case does the calculated value of U have a probability less than .2 under \( H_0 \) on a two-tailed test. (Male Ss, \( U = 24 \), \( p < .44 \); female Ss, \( U = 20 \), \( p < .23 \) for \( n_1 = n_2 = 8 \).) Thus the assignment of Ss to the F and NF groups is without significant bias.

(4) Improvement over two runs, N score

The data concerning the improvement of the F and NF
groups over the two runs is given in Figs. 8 and 9.

Again a notable feature of the results is the prominent number of Ss who decline over two runs. The graphs suggest that the younger Ss are better without feedback whilst the older Ss are better with feedback, in terms of improvement in performance. The table below, Table 3, gives results of Mann-Whitney tests on the various categories of Ss.

**TABLE 3**

Improvement in the Number of Responses to Negative Stimuli over Two Runs

<table>
<thead>
<tr>
<th>Group</th>
<th>Result of one-tailed Mann-Whitney tests to see if F group improves more than NF group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Male Ss</strong></td>
<td>the improvement of the F gp is not significantly better than the NF gp at the 0.05 level (U = 14, p &lt; .032, n1 = n2 = 8)*</td>
</tr>
<tr>
<td><strong>Younger Female Ss</strong></td>
<td>the improvement of the F gp is not significantly better than the NF gp at the 0.05 level; U = 26.5, p &lt; .287, n1 = n2 = 8</td>
</tr>
<tr>
<td><strong>Combined Male and Female</strong></td>
<td>the improvement of the F gp is not significantly better than the NF gp at the 0.05 level (U = 78, critical value 83 at 0.05 level, n1 = n2 = 16)*</td>
</tr>
<tr>
<td><strong>Male Ss</strong></td>
<td>the improvement of the F gp is significantly better than the NF gp at the 0.1 level; U = 19, p &lt; .097, n1 = n2 = 8</td>
</tr>
<tr>
<td><strong>Older Female Ss</strong></td>
<td>the improvement of the F gp is significantly better than the NF gp at the 0.05 level; U = 13, p &lt; .025, n1 = n2 = 8</td>
</tr>
<tr>
<td><strong>Combined Male and Female</strong></td>
<td>the improvement of the F gp is significantly better than the NF gp at the 0.01 level; U = 64.5, critical value 66 at the 0.01 level, n1 = n2 = 16</td>
</tr>
</tbody>
</table>

* The small value of U and p here does not indicate that the F group is significantly better than the NF group - on the contrary it arises because the F group are so much worse than the NF group. The observed result is in the opposite direction to the predicted result on the Luria hypothesis; see the discussion section.
(5) As with the missing responses the next feature of the results examined is the relation between improvement over two runs and the initial level of performance. The graphs below, Figs. 10 and 11, show the results for the two age groups, and the two experimental conditions with male and female Ss treated together. As would be expected from the form of the graphs the only significant correlation to be found between improvement and initial level of performance is for the older P group ($r_s = .78$ which is significant at the .02 level for a two-tailed test). For the remaining groups no correlation achieves significance (for older NF Ss $r_s = .15$; for younger P Ss $r_s = .36$, for younger NF Ss $r_s = .31$).

Proportion of Late Responses

(1) Combining the P and the NF groups together there is no significant difference between younger and older Ss with respect to the proportion of late responses made on the first run. (On a Mann-Whitney test the probability of the calculated $U$ under $H_0$ is $p < .39$ on a one-tailed test with $n_1 = n_2 = 32$.)

(2) Looking at male and female Ss separately for the two age groups there is no evidence that the sexes perform differently. (For young Ss calculated $U = 80$, for older Ss calculated $U = 118.5$; these are not significant at the .05 level on a two-tailed test with $n_1 = n_2 = 16$.)
Improvement over two runs in responses to negative stimuli (Male Ss)

Fig. 8

Improvement over two runs in responses to negative stimuli (Female Ss)

Fig. 9
Relation between improvement in the number of negative responses and the initial level of performance (younger Ss)

Fig. 10
Relation between improvement in the number of negative responses and the initial level of performance (older 63)

Fig. 11
IMPROVEMENT OVER TWO RUNS IN THE PROPORTION OF LATE RESPONSES (MALE Ss)

Fig. 12

IMPROVEMENT OVER TWO RUNS IN THE PROPORTION OF LATE RESPONSES (FEMALE Ss)

Fig. 13
(3) The check for the similarity of control and experimental groups on the first run reveals a snag. The older female NF group are different from the older female P group (U = 13, which is significant at the 0.05 level on a two-tailed test, n1 = n2 = 8). However, if the control and experimental groups are considered as a whole by grouping male and female Ss together a check on each age group separately shows that on the first run there is no significant difference (for younger Ss, U = 118, for older Ss, U = 92.5 which are not significant on a two-tailed test at the 0.05 level, n1 = n2 = 16).

Because of the lack of comparability of the older female subgroup of Ss the only comparisons that will be made using this measure of performance will use male and female Ss combined.

(4) Improvements over two runs, \( L/(L+C) \) score

The overall improvements of the P and NF groups at the two ages are shown in Figs. 12 and 13. There are no significant differences at the 0.05 level between the two experimental conditions. (For the male and female Ss combined the younger Ss give U = 124, the older Ss give U = 86.5, which are not significant at the 0.05 level on a one-tailed test, n1 = n2 = 16.) For the older Ss the calculated value of U is not as close to significance as it might appear because the actual tendency of the data is in the opposite direction to that predicted.
(5) In neither experimental or control groups at either age does there appear to be a significant correlation between improvement and initial level of performance. With male and female Ss grouped together the largest calculated value of $r_s = .53$, which is not significant at the .05 level on a two-tailed test with $N = 16$. (Young NF, $r_s = .53$; young F, $r_s = .45$; old NF, $r_s = .03$; old F, $r_s = .38$.)

Number of Extra Responses

The number of extra responses made by Ss with one or two exceptions was very low, often zero. In the first run 41 of the 64 Ss made no extra responses at all, and only one S as many as 5.

(1) There is no significant difference between the number of extra responses for the first run for all the older Ss compared with all the younger Ss. (On a Mann-Whitney test the one-tailed probability of the calculated $U$ under $H_0$ is $p < .067$, $n_1 = n_2 = 32$.) This result has been corrected for ties owing to the large number of zero scores. This correction can be taken for granted in all results quoted in this section.

(2) Comparing male and female Ss, there is no significant difference on the first run for either the younger or the older Ss. (For young Ss the calculated $U$ under $H_0$ has a $p < .09$, for older Ss $p < .68$ for a two-tailed test with $n_1 = n_2 = 16$.)
(3) The check for the similarity of the F and NF groups on the first run reveals no significant differences. (Taking young Ss first, on a Mann-Whitney test the two-tailed probability of the calculated U under $H_0$ for male Ss is $p < .69$, for female Ss $p < .74$, $n_1 = n_2 = 8$ for combined male and female Ss $p < .72$, $n_1 = n_2 = 16$. For older Ss males give $p < .44$, females $p < .88$, again on a two-tailed test with $n_1 = n_2 = 8$.)

(4) Improvement over two runs, $E$ score

There are no significant differences at the .05 level on a one-tailed test between the F and the NF groups. (The one-tailed probabilities of the calculated U under $H_0$ on a Mann-Whitney test for the different categories of S is as follows: young males, $p < .44$, young females $p < .12$, combined males and females $U = 116.5$; the calculated values of U are not significant on a one-tailed test at the .05 level with $n_1 = n_2 = 16$.)

Figs. 14 and 15 indicate the mean level of improvement for the different groups.

(5) For the NF groups neither young nor old Ss showed any significant correlation between amount of improvement and initial level of performance. The old F group, however, showed a significant correlation in that the worse the initial performance the greater the improvement. (For young NF, $Ss r_s = .16$, old NF, $Ss r_s = .02$; for young F, $Ss r_s = .59$, for old F $Ss r_s = .73$. The last value is significant at the .02 level on a two-tailed test with $N = 16$.) See Figs. 16 and 17.

* Insert: old males $p < .20$, old females $p < .48$, combined male and female $U = 116$;
IMPROVEMENT OVER TWO RUNS IN
THE NUMBER OF EXTRA RESPONSES (MALE Ss)

FIG 14

IMPROVEMENT OVER TWO RUNS IN
THE NUMBER OF EXTRA RESPONSES (FEMALE Ss)

FIG 15
RELATION BETWEEN IMPROVEMENT IN NUMBER OF EXTRA RESPONSES AND INITIAL LEVEL OF PERFORMANCE (YOUNG Ss)

FIG. 16
RELATION BETWEEN IMPROVEMENT IN NUMBER OF EXTRA RESPONSES AND INITIAL LEVEL OF PERFORMANCE (OLD Ss)

FIG. 17
Discussion

First a summary of the results. With the exception of the number of missing responses age does not influence the initial level of performance. Male and female Ss behaved the same way on the first run for all measures of performance.

With regard to the relative improvements of the Feedback and No-Feedback groups over two runs, there was no significant difference at all on two of the measures of performance: these were the number of extra responses and the proportion of late responses. For the number of missing and negative responses, however, the effect of feedback as shown by improvement over two runs was, in some cases, significant. For both scores the younger Ss taken altogether show no improvement with feedback greater than that shown by controls, but the older Ss taken altogether do show a greater improvement with feedback than without.

Looking now at male and female Ss separately it is found that for the number of negative responses both the older males and older females show greater improvement with feedback than without, whereas neither younger males or younger females do so at all. A similar breakdown for the missing responses is not so neat. The older males, though showing a greater improvement with feedback than without, are not significantly better, whereas the younger males do improve significantly more with feedback. Nevertheless, in the breakdown, three
out of the four groups that show the influence of feedback are older Ss, and grouping males and females together, as remarked above, shows older but not younger Ss improving with feedback.

Some idea of where the improvement comes from is given by the fact that for three of the scores (missing, negative and extra) the older Ss with feedback show a significant correlation between the number of mistakes made on the first run and the amount of improvement. Feedback seems to benefit the older Ss who had ground to make up on the first run.

Implications for Luria's Feedback Model

At first sight the implications for Luria's hypothesis would seem to be that in some cases it has been borne out and in others it has not. There are, however, two considerations which make the results seem somewhat more radically at variance with Luria's ideas.

The first point is that older rather than younger Ss make up the bulk of those that show an improvement in performance as a consequence of having exteroceptive feedback. This is not at all what would be expected on Luria's account of the role of feedback. Luria explained the limitations of young Ss to perform the sort of task dealt with in this experiment in terms of bad proprioceptive feedback. If inadequate proprioceptive feedback is a characteristic of young children then the process of physiological maturation would
remedy it; consequently the older the child the better his proprioceptive feedback. This means that the possible help to the child of giving exteroceptive feedback should show diminishing returns. In fact the help given by exteroceptive feedback, rather than diminishing with age, on the whole increases with age. So the results go in the opposite direction to those predicted by Luria.

The second way in which the results differ from Luria's ideas is that not only does feedback often help the older child rather than the younger child, it often appears to make the overall performance of groups of younger children worse. But this point must be heavily qualified because for the younger male Ss feedback does have a significant improving effect on the number of missing responses. Secondly the statement that some groups of younger Ss are worse with feedback cannot be offered as a statistically significant claim.

Although the results of Exp. 1 are not in accord with Luria's predictions they are in conformity with other results concerning age related trends in the ability of Ss to utilise information from more than one source. Birch and Lefford (1967) showed with a figure drawing task that as children grow older they become increasingly capable of treating ancillary visual information as a facilitator rather than a distractor in a motor task. In the present experiment the ancillary information is not visual but consists in the auditory
cues from the buzzer, but as with Biroh and Lefford’s study children under 6 do not appear to benefit from the extra information.

The impression given by Yakovleva’s experiment, quoted earlier, is that feedback has a very marked effect on children’s performance. Such a result is not improbable in view of other reports which have attributed rapid and quite remarkable increases in subtle muscle control to the introduction of exteroceptive auditory feedback, for example Basmajian (1963) and Hardyck, Petrenovich and Ellsworth (1966). The former experiment in particular (in which single motor units of the right abductor pollicis brevis are brought under the control of the will simply by providing auditory feedback from them) is clearly analogous to Yakovleva’s experiment and would point to the result claimed. The present experiment, however, throws doubt on the idea that auditory feedback is much help to the very young children (such as the younger group in this experiment). Secondly, it throws doubt on the explanation that the limitations in their performance is due to bad proprioceptive feedback. Third, where feedback does have an effect which is statistically significant its effect on individuals is not a strong one.

* But see the criticisms of the experimental procedure by McGuigan (1967).
An Alternative Explanation

The results so far have been looked at exclusively in terms of feedback as a carrier of information, but feedback can often have an 'arousing' function. The results of this experiment could just as well be approached in terms of the buzzer heightening the arousal of S as rather than it supplying them with missing information. Broadbent's (1963a) review of work on the interaction of stresses shows that it is plausible to view noise as a source of arousal, and this explanation would fit the general trend of the results quite neatly. Suppose that an increase in arousal helps to improve performance up to a certain point beyond which it detracts from performance. (The mechanism which might underlie this form of the Yerkes-Dodson Law have been outlined by Welford (1962) and Hebb (1955).) Assume as well that the crucial point of inflection corresponds to a higher arousal level the older the child. Given these premises it would be predicted, contrary to Luria, that older children would benefit more than younger children from feedback which increases the level of arousal. Younger children would frequently be at the stage where any increase in the level of arousal would cease to pay dividends and possibly even hinder performance.

A graphic description of the tension observable in young children in reaction time experiments is provided by Goodenough (1935), but it would be wrong to assume
any simple relationship between physiological and behavioural measures of arousal. It is known that sleep-loss, which almost certainly acts to lower arousal (Broadbent, 1963b) can be accompanied by heightened muscle tension (Malmo and Surwillo, 1960). However, the early work of Duffy (1932a, b) does establish that in young children muscle tension has an inverted U relation to performance on discrimination and tapping tasks.

An arousal theory similar to the one sketched above is as available in neo-Pavlovian concepts as it is in standard Western theoretical terms. Neo-Pavlovian theory would see the point of inflection as being the so-called 'threshold of transmarginal inhibition'. This is the point at which the 'law of strength', which states that there is a proportionality between the intensity of a stimulus and the response magnitude, gives way to the operation of transmarginal inhibition, where increase in stimulus intensity inhibits response. This form of picturing physiological processes also distinguishes 'weak' from 'strong' nervous systems. A weak nervous system has a lower threshold of transmarginal inhibition. The only extra supposition needed to make this theory equivalent to the earlier one would be that the younger the child the weaker the nervous system (see Gray (1964) for the relationship between Pavlovian and Western concepts).

Before an arousal theory can cope with the main
trends in the data a refinement needs to be introduced. So far it has been tacitly assumed that a single inverted U-shaped curve gives the relationship between performance and arousal for all performance measures. This is implausible because different measures of performance might be expected to respond to over, or under, arousal in different ways. For example, the M-score deals with responses which have been missed out so this score might be expected to suffer no ill effect from a level of arousal which makes a subject over responsive. By contrast, the N-score deals with responses which ought to have been inhibited. In this case over responsiveness would produce a decline in the measured performance. The refinement that is required is a different inverted U-shaped curve for the two measures of performance. The form of the curves must be that the curve for the N-score will have reached its peak before that of the M-score.

Two such curves are given in Fig. 18 (a) and (b). Consider (a) which deals with the older children in the sample. Let the line AA' represent the level of arousal in the first (no-feedback) run, and the lines BB' and CC' the arousal on the second run with feedback and without feedback respectively. BB' indicates heightened arousal produced by the buzzer and CC' a small decrement produced by slight fatigue or boredom on the second run with no feedback. These three lines will produce the main trends of the observed results in
that feedback both decreases the number of responses missed out and reduces the number of responses that should not have been made. Now consider (b) which represents the situation for the younger children who are assumed to be functioning at a higher level of arousal. Let the lines AA', BB' and CC' have the same meaning as above. In this case the effect of the buzzer is to take the Ss level of arousal over the peak of both the curves. The result will be very little change in the number of responses missed (because of the symmetry of the M-curve) but a marked decline in performance as measured by the number of negative responses (because of the relative positions of the curves on the x-axis).

This picture is slightly too simple because it does not differentiate between the male and female Ss who, in the younger group, behave slightly differently. The female Ss on one plausible interpretation of the data are slightly more arousable than the male Ss. This trend, only less marked, can also be discerned in the older Ss. Despite slight oversimplification the arousal theory explains all the main trends in the data and in particular it explains why the younger Ss with feedback show an improvement as measured by the number of missing responses and a decline as measured by the number of responses to negative stimuli. It is worth noting that had the experiment been approached with the arousal picture in mind, as the hypothesis to be tested,
HYPOTHETICAL AROUSAL FUNCTIONS TO ACCOUNT FOR MAIN TRENDS IN THE RESULTS OF EXPERIMENT 1

Fig. 10
then the data concerning the N-score would have permitted the conclusion that the predicted decline was a statistically significant one (see the data in Table 3).

Three limitations of the above account are as follows: First, it cannot account for the data concerning extra responses or the ratio of late responses. No significant differences in these response measures were detected between the various experimental conditions so this is perhaps no serious shortcoming. Second is the prima facie problem that younger Ss are supposed to be functioning at a higher level of arousal than older Ss in the first (no-feedback) run, and yet they miss out more responses. The arousal theory may be able to reconcile these demands by stressing that whilst changes in arousal produce changes in performance, the level of arousal does not determine absolute levels of performance. Hence the initial level of 'noise' in the response system is an independent parameter. Third, and most important, is the fact that explanations in terms of hypothetical arousal functions are very weak unless some experimental measure of arousal is used to provide a constraint on the choice of theoretical curves used in the explanation. For a general discussion of such adequacy requirements see Broadbent (1963b) and Corcoran (1965). Despite these shortcomings the arousal theory shows more promise than one in terms of lack of proprioceptive feedback.
Conclusion

One of the proposed bases for understanding the regulatory function of language has now been subject to both a theoretical and experimental examination. The theoretical scrutiny suggested that it was not clear how the feedback result was in fact functioning as a model for Luria. Now it has been shown that the process is not, in any case, available in the required form to function as a model at all. However, the central requirement of the Vygotsky Condition has not been touched. This is the requirement that the speech system be superior to the motor system in its ability to organise and time responses. A direct examination of this claim will be the subject of the next experiment. Using the language of the Shunt Model the next experiment will ask whether the verbal system really can take a greater *current* of excitation than the motor system.

EXPERIMENT 2. COMPARISON OF VERBAL AND MOTOR RESPONSES IN 4 AND 5 YEAR OLDS

In this section one of Luria’s very basic claims will be examined. This is the claim that in young children the verbal system is superior to the motor system in terms of its ability to organise and time responses, say, to sequences of signals. The somewhat surprising nature of this claim should not be missed. Although the speech system and the motor system have, for the purposes of exposition, been treated as if they
are two different things, it is of course true that speech can also be looked upon as a motor skill, especially when used in the limited way that it is in the Luria type of experiment. In this case the claim to be considered is that such a well practised activity as grasping things is inferior to what is probably a less well practised activity, viz. forming words. Adding to the paradoxical nature of Luria's claim is the well known fact that for adults the verbal R.T. is longer than the motor R.T. (Wells, 1924) leading to the suggestion (Woodworth, 1938) that verbal R.T.'s may be more complex (p. 329). There is, however, a result which seems to conform to Luria's requirements. Alluisi, Muller and Pitts (1957) found that with the forced-paced, serial presentation of arabic numerals, number naming responses were more efficient than key-pressing responses. Indeed the rate of transmission of information was some three times higher for the verbal system. But this does not necessarily establish the superiority of the verbal system as such because the well learned association between the stimulus and response in the naming task could account for the result (cf. Exp. 7 below).

As was stated earlier, the superiority of the verbal system is a central requirement of any theory which gives the verbal system the role of taking over and improving motor performance. This requirement was termed the Vygotsky Condition. Luria explicitly
recognises this condition, for he says, when applying
his ideas to the behaviour of cerebro-asthenic children,
'only when the neurodynamics of their verbal processes
prove to be more intact, shall we be able to utilise
these processes as a means of compensating for the
defects so clearly observed in the motor reactions'
(1961, pp. 76-7).

Describing an experiment on normal 3-4 year old
children Luria says that when they were asked to make
verbal responses to signals,

they did not experience any appreciable diffi-
culties in fulfilling the instruction to react
to each signal with the words "Go!", "Go!". This
task interested them greatly; their
verbal reactions were always strictly co-
ordinated with the signals, the latent periods
being much more stable than those in the motor
reactions. In contrast with the experiments
demanding motor reactions, these experiments
resulted in practically no perseverating
verbal behaviour produced independently of the
signal, nor on the other hand did the responses
become extinct.

(Luria, 1961, p. 45)

The following empirical claims can be extracted
from this account:

(1) reaction times to verbal responses are more stable
than to motor responses;
(2) there are fewer extra verbal responses than motor
responses;
(3) there are fewer missing verbal responses than motor
responses.

In the following experiment these claims will be
tested. The experimental technique used will be very
similar to Exp. 1, where some signals require a response, and others the inhibition of a response. This will also make it clear whether verbal responses occur less often to what have been called negative stimuli than do motor responses. The claim that the proportion of late responses is less for verbal than for motor responses can also be tested. (These can be considered as numbers (4) and (5) to be added to the list of empirical claims given above.)

One reason for using the slightly more complex task of Exp. 1 - Luria's experiment just had positive signals - is that the mean age of the Ss will be slightly higher than Luria's. The reason for this was ease of availability. Limitations in the experiment because of this slight age difference will be dealt with in the discussion.

**Hypothesis**

The ability of young children to make verbal responses to sequences of blue light signals but not to interspersed yellow light signals is greater than the ability to perform the corresponding motor task where the response consists in pressing a small rubber bulb held in the hand. 'Greater ability' is defined in terms of fulfilling the five empirical claims listed above.
Subjects

The details of the Ss are given in Table 4 below. The Ss were drawn from the Drummond Street School as in the previous experiment.

TABLE 4
Details of the Subjects of Experiment 2

<table>
<thead>
<tr>
<th>Subject Group</th>
<th>Number</th>
<th>Mean Age in Months</th>
<th>S.D.</th>
<th>Mean Peabody Test Score*</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger Ss</td>
<td>16</td>
<td>52.5</td>
<td>4.9</td>
<td>47.7</td>
<td>6.5</td>
</tr>
<tr>
<td>Older Ss</td>
<td>16</td>
<td>70.2</td>
<td>6.7</td>
<td>53.1</td>
<td>4.2</td>
</tr>
</tbody>
</table>

* Raw Score. See Appendix I.

Design

The experiment was designed to compare verbal with motor responses on the same task. Each S was used as his own control and given two experimental runs, one making verbal responses, one making motor responses. Half of the Ss performed the motor task first, half the verbal task. Equal numbers of boys and girls were used, the same number of each sex being assigned to each of the two orders of presentation. Two age groups were used, with N = 16 for each age. The task given to Ss was the same as in the first experiment, except that in one run the S is to utter the word 'go!' rather than press the response bulb.
Apparatus

This was the same as in Exp. 1. The stimulus values were also exactly the same as those used previously. The only difference in the apparatus was that for the verbal trial the Ss held in their hand a small, light microphone into which they spoke. This microphone produced a signal on the event recorder. Unlike the motor run a continuous trace rather than an on/off signal was used.

Scoring Criteria

The different categories of mistakes were the same as those used in Exp. 1. The only significant difference in scoring in this experiment lies in the fact that for the verbal responses a decision had to be made as to when a trace indicated a signal and when it indicated mere background noise. Such a decision is in the last resort arbitrary but it must be made consistently and objectively. Examination of the various response traces led to a decision to count as a response any trace which was displaced from the midline by over two millimetres for a distance of up to or over five millimetres; given the speed at which the recording paper was passing through the recorder this corresponded to a time of one quarter of a second. This criterion cut out the spiky traces which checks revealed were merely due to breathing, but it caught those occasional whispered responses whose traces were less obvious than
the traces of clearly spoken responses.

Procedure

This was very similar to Exp. 1. Ss were trained up to the same criterion as in the previous experiment, given the first run, trained up to the same criterion with the new response, then given the second experimental run. The only real difference, then, lay in the training to make the verbal response.

In being introduced to the verbal response Ss were first shown the little spot of light on the event recorder. (The apparatus in question was an A.E.I. Oscillograph which recorded a trace on light sensitive paper.) They were shown how the spot shot back and forth when E spoke loudly into the microphone, and how it hardly moved at all when E whispered. The microphone was then handed to S who was told to say his name loudly into the microphone and to repeat the numbers 1, 2, 3... whilst looking to see how the spot of light moved. The purpose of this was to give the S some indication of what loudness of voice was wanted and give him some incentive to speak in a normal speaking voice rather than a whisper. The S was told to speak so as to make the spot move a lot. It also helped Ss to be aware of how to direct their voice into the microphone. Pilot experiments without this special training procedure had shown that Ss were prone both not to speak into the microphone, perhaps letting it rest in
their lap, and, significantly, to let their verbal response lapse into a whisper or even a mere mouthing of the response word. Having established the sort of response wanted, the Ss practised with the response 'go!' in front of the stimulus screen with stimuli being presented manually until they achieved the stated criterion. Here again great attention was paid to encouraging Ss to maintain a speaking voice rather than lapse into a whisper.

**Results**

The results will be analysed in the following order: (i) missing responses, M, (ii) responses to negative stimuli, N, (iii) proportion of late responses to late plus correct responses, L/(L+C), (iv) extra responses, E, (v) reaction times. The study of reaction times will involve a direct comparison of the mean lengths of motor and verbal reactions and a comparison of their 'stability', or variability.

**Missing Responses**

The data concerning the mean number of missing responses made in the different conditions for the two age groups is given in Fig. 19. Wilcoxon tests were carried out to compare the verbal and motor performance of all the younger Ss, then all the older Ss, then the male and female subgroups at each age. No significant differences were found. However, if all Ss, of both
ages, are grouped together a significant difference in the predicted direction is found between verbal and motor responses. \( z = 2.27 \) \( p < .012 \) on a one-tailed Wilcoxon test, \( N = 29 \). So, overall, verbal responses are better than motor responses with regard to the number of missing responses.

**Negative Responses**

Fig. 20 shows the overall performance with the two types of response for the two ages. Wilcoxon tests reveal no significant differences between verbal and motor responses for any of the groupings or breakdowns used in the section on missing responses. These same groupings and breakdowns of the Ss will be used in all the remaining response measures.

**Proportion of Late Responses**

Fig. 21 gives the overall performance for the two types of response at the two age groups. Wilcoxon tests reveal no significant differences between verbal and motor responses.

**Extra Responses**

Again no significant differences are to be found using Wilcoxon tests between the verbal and motor responses. Fig. 22 gives the overall performance levels at the different ages.
COMPARISON OF THE NUMBER OF MISSING VERBAL AND MOTOR RESPONSES

FIG. 19

COMPARISON OF THE NUMBER OF VERBAL AND MOTOR RESPONSES TO NEGATIVE STIMULI

FIG. 20
COMPARISON OF THE PROPORTION OF LATE MOTOR AND VERBAL RESPONSES

FIG. 2.1

COMPARISON OF THE NUMBER OF EXTRA MOTOR AND VERBAL RESPONSES

FIG. 2.2
Reaction Times

For each S two mean reaction times were calculated, one for the motor response, one for the verbal response. Wilcoxon tests show no significant difference between them (see Fig. 23). To compare the stability of responses, the range of reaction times for each of the two types of response was calculated for each S. The range equals the difference between the longest and the shortest reaction time. Again, Wilcoxon tests did not show any significant differences.

Discussion

The hypothesis of the superiority of verbal responses over motor responses is only very weakly supported. With one exception the results do not conform to Luria's hypothesis. Luria predicts that in a variety of respects timing, number of missing responses, number of extra responses, the verbal system should produce a superior performance to the motor system. In the present experiment this is not, in general, true. The one result which does conform to his prediction is that significantly less verbal than motor responses are missed, but although this effect is statistically significant it is not strong. The result, then, does not provide much evidence that the Vygotsky Condition is satisfied, as is required if language is to be given a regulatory function.

There is, however, a reason for thinking that the
COMPARISON OF THE MEAN REACTION TIMES OF THE MOTOR AND VERBAL RESPONSES

FIG. 2.3
significance of this experiment may be limited, because the Ss (even in the younger group) are a little older than the 3-4 year olds used by Luria. The argument based on this fact is as follows: because of the age of the Ss the motor responses (possibly with help from the speech system) have already achieved a high level of performance. Consequently the fact that the speech responses are not noticeably better than the motor responses is to be expected. Only if the motor system is examined with younger Ss at a stage when it still shows considerable deficits will the superiority of the verbal system become apparent. The crucial tacit premise of this argument is that both systems are working at a level of near perfection. The very low average number of extra and negative responses fits in with this interpretation. The error score which shows a large average number of mistakes is the M score for missing responses: it is this score on which the verbal system does show itself up to be superior to the motor system.

In the light of this argument the result of the experiment should perhaps be expressed by saying that on the one response measure where the alleged superiority of the verbal system might show itself, it did so. So it is only with regard to the M score that this experiment constitutes a genuine test of the hypothesis; and the hypothesis passes the test.

The argument just examined suggests that Luria's
prediction has perhaps been as well verified as the circumstances of the experiment permit. This conclusion must be subject to two qualifications. The first has already been mentioned; it is that the superiority of the verbal system, as regards missing responses, though significant, is not marked. The second and related point is that according to the quotation given earlier from Luria the verbal responses of the 3-4 year old child were, apparently, almost faultless and there were 'no appreciable difficulties in fulfilling the instructions'. The results of this experiment, however, show that for the younger Ss there was an average of 10 missed verbal responses out of 30 possible. So one third of the required verbal responses were missed, even though the children were older than Luria's Ss. Here, then, the argument about the near perfection of performance reverses itself. According to Luria when the Ss were responding verbally their performance should have been nearly perfect, when in fact it was only about two thirds perfect. So even if it is granted that the verbal system is superior to the motor system, as Luria predicts, the absolute level of verbal performance falls considerably short of what Luria suggests, and to this extent falls short of the requirements of the Vygotsky Condition. In terms of the Shunt analogy this means that there does not seem to be much scope for the verbal system to prevent the motor system from becoming overloaded. It would be like
trying to protect a sensitive instrument in an electrical circuit by a shunt that could not carry the bulk of the current.

**Conclusion**

In outlining Luria's development of Vygotsky's ideas a variety of theoretical levels of generality were distinguished. At the lowest level of generality were the two different models which Luria has used to explain in detail how verbal system regulates the motor system. The first of these models to be outlined, the Feedback Model, has been tested in Exp. 1 and found wanting. The second model, dubbed the Shunt Model, is a particular form of the Vygotsky Condition and has in some measure been tested in Exp. 2. This experiment was not perfectly focused: the Ss were some 5 months too old for it to be a direct test of Luria's claim about the relative diffuseness of the verbal and motor systems. Despite this the experiment revealed a level of inadequacy in the verbal system which does not conform to the requirements or expectations of Luria's account.

It would be exaggerating to say that the two models at the base of the theoretical hierarchy have been refuted by Exps. 1 and 2. But these experiments suggest that it might be more fruitful to pitch the rest of the investigation at a slightly higher level of generality; that is, to focus on the general claim that
verbal processes are intimately involved in the organisation of motor responses in the form of self-instructions.

The general form of the thesis that language regulates and organises ongoing motor behaviour will now be constructed by quotations from Luria's work. The content of these propositions, along with deductions drawn from them, will from now on be collectively referred to as 'Luria's theory' or the 'regulatory thesis'. This general form of the regulatory theory will be the subject of experimental test in subsequent chapters.

The General Form of the Regulatory Theory

One major component in Luria's theoretical standpoint is his belief that even the most simple responses in the older child and adult bear the stamp of the higher mental functions or intelligent thought. In taking this position he is reacting against a view of human behaviour which sees its complex forms as a mechanical accumulation of 'atoms' of simple reflexes. Luria's is a dialectical view which allows the higher mental functions to possess autonomous principles of operation which then filter down and modify the workings of the simpler processes. This characteristic mode of thinking is brought out in the following quotations:

The reactive process of the human adult cannot be explained as a mechanical habit, it is constructed not only from below, but from above, it includes within itself the regulating systems of a higher psychological order.

(Luria, 1932, p. 395)
The usual conception of the development of a child's motor skills as a gradual progression from the lower forms to the higher, gives way here to another...the processes which we consider simple depend upon much more complicated ones, including them as hidden mechanisms.

(Ibid., p. 421)

The internal structure of the simple reactions is thus a very complicated one and we should search for the specific mechanisms concealed within it and having to do with its regulation.

(Ibid., p. 388)

The higher order processes which are concealed in the structure of even very simple responses 'as hidden mechanisms' are verbal in character.

Precisely in the activity connected with speech we succeeded in observing the transfer from the primitive, diffuse and direct process to the process splitting into two functionally different phases - the phases of preparation and of execution. By virtue of speech, the primitive impulsiveness is overcome, and the direct attempts of adaptation are substituted by the preliminary connection in words; after this comes the motor execution.

(Ibid., p. 389)

(For clarification of the idea of the two phases see Fig. 2(b) where they are indicated.) On the basis of clinical observation Luria adds to the above that:

the limits of speech are not where we are accustomed to see them...numerous functions externally having nothing to do with speech are actually verbalised, and after impairment of the speech function, they drop out.

(Ibid., p. 389)

Luria also outlines the general technique whereby his theory could be tested and these will be briefly given to show that the experimental approaches used in later chapters are of the sort that the originator of
the theory would accept as legitimate tools for investigating his ideas. First of all he recommends that highly practised tasks are not used because when a task becomes automatic its structure will not be so accessible; like a tight knot its parts will be inseparable (1932, p. 395). Second is the suggestion that the role of higher processes can be demonstrated by observing the effect of weakening their relative influence.

We attain this by two simple methods: we may use the normal subject while in a condition of extreme fatigue, or we may divert the higher regulators from the reactive function, giving it another load, inducing the subject to change his attention. (Ibid., p. 384)

Such a functional exclusion of the higher cortical mechanisms from participation of the sic simple reactions evokes a return to the primitive, diffuse type of reactive processes.... (Ibid., p. 385)

Finally a quotation will be given to provide a rationale for the choice of age-group of Ss in the forthcoming experiments. What is required are Ss whose behaviour will show (on Luria's theory) a considerable degree of verbal involvement in the organisation of their motor responses and yet who are not of such an age that the verbal processes will have become so habitual that they cannot be interfered with or dislodged. The age selected is around 75 to 80 months (except for a group in the very next experiment where an extremely simple task is used), so this takes the Ss comfortably within the category required as judged by the following claim:
When a child develops normally, the closest interaction of the two signal systems is established as early as the age 5 or 6, and under laboratory conditions, the abstracting and generalising function of language begins to play a decisive role in the development of new connections.

(Luria, 1957, p. 124)

These quotations will have made concrete the form of the theory which will be the object of scrutiny from now on. This general form of the theory carries at least a suggestion that the thesis of verbal self-regulation should now be interpreted as the slightly weaker claim for the importance of verbal participation in the organisation of motor responses. In the light of Exp. 2 the greater independence of the theory from the demands of the Vygotsky Condition is perhaps fortunate. In Chap. II some very simple forms of motor response will be considered and their relation to the verbal system investigated. In Chaps. III and IV somewhat more complicated and revealing tasks will be studied by the techniques and approaches worked out in Chap. II. In the next chapter the beginnings will also be seen of an alternative theory to the regulatory picture outlined above; this will have emerged fully by Chap. IV where it will stand in full opposition to Luria's approach.
CHAPTER II

SOME SKINNERIAN WORK ON VERBAL SELF-REGULATION

There have been a number of studies in the Skinnerian framework which bear on the general claim that language has a regulatory function. These studies have been explicitly related to Luria's ideas by their authors. The manner in which they have interpreted him make their work an appropriate starting point for an investigation into what has been called the general form of the regulatory theory. Two of these works will be reviewed in detail, and, in the light of some methodological criticisms the third and fourth experiments of this study will be presented.

Review of Experiments

Lovaas (1964) investigated how the rate and content of verbal operants can control operant manual responses. His first experiment established that the rate of overt, repeated counting of the numbers 1 to 5 influenced the rate at which a lever was pressed. Four Ss (4-5 - 5-2) were trained to count rapidly to one colour of light and slowly to another colour. They were then told to press a lever up and down whilst counting. The Ss were not told to press either rapidly or slowly. The lights were presented randomly over a period of five minutes, at 10 sec. intervals, each light flash lasting 20 secs. Ss received rewards of tokens (to be exchanged for toys)
on a fixed interval 10 sec. schedule, provided that they were counting.

The next experiment showed that under similar conditions certain Ss would spontaneously repeat the word 'faster' at a greater rate than the word 'slower'. This shows that the content of a verbal operant can affect its rate of production. Of the ten Ss completing this experiment this conclusion applied to the six older children (5-2 - 7-4). One child (5-1) showed the reverse effect and the three younger children (4-9 - 4-10) showed no significant difference in speed of production. The mechanical difficulties of word production could not account for the result because the available data (cited by Lovaas) would produce the opposite prediction.

Lovaas' third experiment studied the effect of the content of a verbal operant on the latency of a non-verbal operant. The Ss (three groups of 7 children aged 6, 9 and 11 yrs.) were trained to respond with the word 'faster' to one light and the word 'slower' to another light, until the discrimination was firmly established. The latencies of a lever pressing response under alternate presentation of the lights were then observed. There was a 5 sec. interval between light presentations, and each signal was terminated by the lever press. Ss were rewarded every \( \frac{1}{20} \) sec. for light-off periods. The latencies for the 'faster' light were significantly shorter than latencies
for the 'slower' light. There were also significant differences between the age groups. The mean differences between the latencies for the fast and slow lights increased with the age group of the Sg.

Lovaas also discusses two further experiments not reported in detail. One of these will be noted here because of its bearing on the forthcoming experiments. Lovaas investigated whether the rate of a non-verbal, lever pressing task could be controlled by the content of a verbal response of 'fast' or 'slow'. In previous training the words had been associated with different stimulus lights and these were then presented alternately. With 5 and 6 yr. olds Lovaas says that, "only sporadic and weak control was observed over the manual operants". Pre-training altered the situation markedly, because, "where S's manual responding was first brought under the control of A's [adult's] verbal behaviour, then S's own verbal behaviour would control his own manual responding". Some comments will shortly be made about this experiment.

Meichenbaum and Goodman (1969) cite Lovaas' work (along with Bem (1967) and Birch (1966)) as contributing to Luria's picture of the developmental growth of the verbal system as a regulator of the motor system. Their experiment examined the "relative efficacy of the differential modes of delivery of verbalisations in governing non-verbal behavior". They used a task similar to Lovaas' in which a child is instructed to tap
whilst the words 'faster' and 'slower' are repeatedly verbalised: (1) by $E$; (2) by $S$, aloud; (3) by $S$, whispering. The amount of verbal control of behaviour, they argued, is indicated by the degree of change in the rate of tapping.

After being divided into three groups corresponding to the three modes of presentation of the verbal command the $S$s were given six different tasks, with two 15 sec. runs per task. First there was an operant (baseline) task in which $S$s were just told to tap without any speed being specified. Second there was a tapping task in which the word 'letter' was uttered. Third and fourth came the 'faster' and 'slower' tasks, whose order was counterbalanced. Fifth came another 'letter' task, and finally another purely operant task. In the 'faster' and 'slower' phases of the experiment, and in all three experimental conditions the $S$s were instructed to "tap the way the word means".

The results showed that the mode of delivery of the verbalisation is an important variable. For example, for first graders (6-7 yr. olds) the increase in the rate of tapping "was equally effected when the verbalisation 'faster' was externally or covertly administered, and had least functional significance when the self-verbalisation was overt" ('external' refers to $E$'s delivery of the verbal response). For kindergarten children (5-6 yr. olds) the external and overt conditions had equal control over tapping speeds, the
covert conditions least. The same is true for the 'slower' task when allowance is made for the fact that Ss respond using the previous level of performance (either 'letter' or 'faster') as a base line.

These experiments establish some basic results regarding the regulatory function of language. They also raise some important methodological issues concerning experimental method, theory and presentation of results. These will now be examined.

**Methodological Comments**

First some observations on Lovaaes' paper. Certain crucial facts about the experimental situation are missing from the paper so that its full significance cannot be assessed. That the facts in question are missing is not a mere shortcoming of the presentation. It seems to result more from the way the experiments have been conceptualised in the first place.

In Lovaaes' first experiment the Ss had to count rapidly or slowly and at the same time press a lever. They pressed rapidly when they counted rapidly and vice versa. Might the children have thought that they had been asked to press the lever rapidly when they counted rapidly? The experimenter carefully refrained from specifying how the child should press the bar hoping that from this deliberately manufactured lacuna in the situation a clear link between language and action would emerge. The experiment depends on this gap; but what
if there is no gap as far as the child is concerned? The possibility that the child has filled in this gap by assumption cannot be lightly dismissed. Lovaas unwittingly provides evidence on this question. He reports that the children offered elaborate hunches about the purpose of the experiment and evinced complex beliefs about the events in the experimental situation (e.g. "odd numbers always seemed to go with the blue light except after the marbles", the marbles being used for rewards). That a deliberately produced gap in the Ss' understanding should be filled with plausible assumption is thus quite possible. (This criticism is a generalisation of Bartlett's (1932) criticism of Ebbinghaus. The basic point is that the complexity of a response is a function of the complexity of the responding organism rather than of the simplicity of the stimulus situation as judged by some arbitrary criterion.) The methodological moral for child psychology is that the experimental situation should not be under-determined lest uncontrolled factors intrude as a result of the child's assumptions and beliefs.

A related problem lingers around Lovaas' account of the influence of the content of a verbal operant on the rate of lever pressing. Lovaas says that without pre-training, "At best, only sporadic and weak control was observed over the manual operants." It is not clear what this means. One hypothesis as to what it means, for which there is no counter-evidence in Lovaas' paper,
is that because the Ss had not even been told that they were expected to press the lever, let alone press it in any given way, then they naturally did not do so. What was the S given to understand about what others expected of him? This crucial information is missing. In its place there is a sentence whose meaning is unclear. The same applies to the account of the pre-training which did result in lever pressing. What is it to bring "Ss manual responding under the control of A's [adult's] verbal behaviour"? Did the adult tell the child to press rapidly when saying 'fast'? The whole of this objection can be expressed by saying that the experimental account is 'theory-laden'. An operational definition is required of the terms used, or else an adequate explanation in terms of familiar, everyday concepts. This second criticism relates to the first criticism, regarding gaps in the instructions, because adopting the technical vocabulary of some theoretical standpoint carries the danger that its users will simply overlook the necessity to clarify issues, or guard against dangers, that are significant from the standpoint of either common sense or other theories.

An objection to the second of the above criticisms is that it applies to an experiment that was only briefly discussed and consequently to a result that is unlikely to be perpetuated in the literature. In reply it need only be pointed out that Meichenbaum and Goodman cite the result of Lovaas' that is in question without
regard to the obscurity of the presentation. Indeed they use the same opaque phrasing as Lovaas.

A similar criticism, regarding the theory-laden nature of the reporting of results, can also be made out against Meichenbaum and Goodman. In this case it does not obscure the experimental results, but it does obscure their possible significance. Consider their sentence, "An interesting finding was that for first graders overt self-verbalisations had less functional control over motor behavior than covert self-verbalisations" (p. 564). This sentence, though a true report of their findings, gives the impression that overt self-verbalisation still has some 'functional control over motor behaviour' for first graders. In fact the relevant graph in the paper (Fig. 2) reveals that the mean number of taps accompanied by overt uttering of the word 'faster' is less than the mean number of taps on the first run, that are not accompanied by any verbalisation. The terminology of 'functional control' is obviously being strained, and its tenacity seems to be preventing the radical alternative formulation of the result: namely, that, far from exerting control, the overt verbal responses are simply interfering with the motor responses.

It is revealing to adopt this alternative standpoint in a completely general way when looking at Meichenbaum and Goodman’s results. This standpoint highlights the fact that because the Ss were told to
press the key "the way the word means", what was being tested was the Ss' ability to obey instructions in a tapping task whilst at the same time performing another task of verbalisation or listening. This formulation of the experiment makes no mention of control or regulation. The results then show that for first graders overt verbalisation interfered most with the task of rapid tapping whereas with kindergarten children whispering interfered most.

This 'mirror-image' formulation thus leads to a theory of 'load' rather than a theory of 'regulation'. It suggests experiments in which the emphasis is on the different loadings imposed on the Ss by having to perform either overt or covert verbal tasks at the same time as motor tasks. From this perspective the regulatory function of language as it occurs in Meichenbaum and Goodman's experiment appears to be an artefact of the experimental situation. This possibility is disguised by the use of theory-laden terminology in the description of the experimental results.

In the light of these methodological comments the next experiments will be presented. Particularly important are the issues raised by the alternative way of formulating Meichenbaum and Goodman's results. This will be the subject of Exp. 3.
EXPERIMENT 3. COMPARATIVE LOAD OF OVERT AND COVERT
VERBAL RESPONSES

The purpose of this experiment is to shed light on the possibility raised in the methodological discussion above, that both overt and covert self-instructions constitute an extra load on the nervous system. This should result in the worsening of the performance of a motor task to be produced simultaneously. An opportunity is also provided to test the hypothesis that the loading imposed by overt and covert verbal responses is differently distributed at different ages. This is the 'mirror-image' formulation of Meichenbaum and Goodman's hypothesis concerning the developmental relation between the regulatory power of overt and covert responses.

The basis of the experiment is to measure the decline in the rate at which Ss tap as rapidly as they can when the motor task is conjoined with overt and covert self-instructions.

Hypotheses

Two hypotheses were tested:

(1) Overt and covert self-instructions will both interfere with the simultaneous performance of a motor task.

(2) For nursery children covert self-instructions will interfere more with a motor task than overt self-instructions. For infant school children overt self-instructions will interfere more than covert self-instructions.
Subjects

The 32 Sa were drawn from the nursery and infants' classes of the Infirmary Street Primary School, Edinburgh. All Sa were free from sensory-motor defects. All children from the infants' classes used participated in this experiment or the next, so that there was no selective process used by either the teacher or E. No selection process needed to be used in the case of the nursery children either, because all of the children were approached to take part. Three of the children refused to accompany E to the experimental room. Of the 16 nursery children who initially took part in the experiment three female Sa declined to complete the task: this accounts for the discrepancy between the final number of Sa in the two age groups. Mention will be made of these three refusals below. Table 5 gives details of the Sa.

**Table 5**

<table>
<thead>
<tr>
<th>Subject Group</th>
<th>Number</th>
<th>Mean Age in Months</th>
<th>S.D.</th>
<th>Mean Peabody Test Score*</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nursery</td>
<td>13 (8 m, 5 f)</td>
<td>52</td>
<td>7.6</td>
<td>50</td>
<td>13.0</td>
</tr>
<tr>
<td>Infants</td>
<td>16 (8 m, 8 f)</td>
<td>75</td>
<td>7.4</td>
<td>56</td>
<td>7.2</td>
</tr>
</tbody>
</table>

* Raw Score. See Appendix I.
Apparatus

The apparatus consisted of a morse key clamped to a table. The key was connected to a small, electrically operated, cumulative counter. The counter could be re-set manually. Each depression of the key was registered on the counter.

Experimental Design

After preliminary training each S was given four experimental runs lasting 15 secs. each. The first and last runs were measures of how fast the Ss could tap a morse key under the instructions to tap as fast as they could. The second and third runs were measures of how fast the Ss could tap the key (1) whilst at the same time repeating aloud the word 'fast', (2) whilst whispering repeatedly the same word. The order of the overt and covert runs was counterbalanced across Ss.

Let the mean score on the non-verbal runs be called $F'$, and the verbal component of the response be signified by the subscript 'f' (short for the word 'fast'), and the overt or covert mode by the prefix 'o' or 'c'. The scores on the experimental runs can then be represented by $F$, $o_f$, and $c_f$ respectively. Abstractly stated the hypotheses then become,

(1) $F > o_f$ and $F > c_f$ for both groups

(2) $o_f > c_f$ for nursery children

$c_f > o_f$ for infant children
Procedure

Ss were approached through the teacher or nursery supervisor. They were told that E had a simple game that they might like to play. Ss accompanied E to an adjacent empty classroom where they were shown the morse key. They were told that it was a 'tapper' which was to be tapped up and down like this ... (E demonstrated). It was pointed out that every tap was counted on the counter. S was then invited to try and show how each of his taps was counted, and was then asked to try to tap fast. Encouragement was given and S urged to tap even faster: 'tap as fast as you can go.' When S appeared to be trying to tap as fast as he or she could the practice runs were terminated and the experimental runs started.

E held a stopwatch in his hand and told S that he (E) would say 'go' and then S was to tap as fast as he could, and keep on tapping, until E said 'stop!' E then said 'go' and did not say anything further until stopping the run. During the run E deliberately did not look at S so as not to distract him. Throughout the run E was seated next to S who was seated before the morse key.

After noting the number of taps and resetting the counter, S was told that he had done well, and the second task was explained. S was told that he was again to tap as fast as he could but was also to say, 'in a nice loud voice so that I can hear you, the words
"fast, fast, fast..." over and over again, all the time that you are tapping'. E then gave a brief demonstration (in the demonstrations the word 'fast' was uttered at the rate of about 4 per sec., the tapping was faster, about 5 taps per sec., no attempt being made to produce one word per tap). The appropriate variations in the instructions were made for the covert run. The performance of whispering was presented by E in his demonstration to Ss as being the mouthing of the word with a just audible sound. A short practice run of about six taps and three or four verbal responses was conducted to ensure that Ss were vocalising or whispering properly. (It was when the nursery children were asked to vocalise that the three Ss mentioned above declined to go on with the experiment. A number of Ss were inclined to speak very softly in the practice run for the overt responses and in such cases the run was repeated to ensure an adequate separation between overt and covert responses. No S who continued with the experiment required more than two brief practice runs, and none had to be rejected because of a lapse into whispering during the experimental run.)

Three further observations about the procedure may be made. First, after Ss had had the various tasks explained to them, the instructions were always repeated immediately before saying 'go'. This ensured that both experimental requirements, of tapping as fast as possible and repeating the word, were prominently before
their minds. Second, a number of the younger Ss occasionally made false starts; they would start tapping before £ said 'go'. Such runs were not, of course, continued. £ was stopped and gently reminded that he must wait for the word 'go'. Third, some Ss were prone to interpret the request for rapid tapping as a request for forceful tapping, banging the morse key with the palms of their hands. This tendency was eliminated during training, all Ss learning to hold the key while tapping.

A few days after the experiment had been performed all of the Ss were given a modified form of the Peabody Test (see Appendix I).

Results

First of all the results of the older, infant group will be examined, and then those of the younger, nursery group. Third, the relation between these findings will be examined. In all cases the results of the male and female Ss will be grouped together as there are no significant differences between them.

Infant School Group

1. Non-verbal and overt scores.
   $F > c_{Ff}$, for every S.

2. Non-verbal and covert scores.
   $F > c_{Ff}$, significant at the .005 level, on a one-tailed Wilcoxon test ($T = 8, N = 15$, where N is the
number of pairs of scores whose difference is non-zero).

3. Covert and overt scores.

\( \text{o}_{F_f} \) is not significantly greater than \( \text{c}_{F_f} \) at the .05 level on a one-tailed test \((T = 38, N = 16, \text{using the approximation recommended by Siegel (1956, p. 79)}, \text{this gives } z = -1.55, p < .06)\).

Nursery School Group

1. Non-verbal and overt scores.

\( F > \text{o}_{F_f} \) significant at the .005 level on a one-tailed test \((T = 1, N = 11)\).

2. Non-verbal and covert scores.

\( F > \text{c}_{F_f} \) for every \( S \).

3. Covert and overt scores.

\( \text{o}_{F_f} \) is not significantly greater than \( \text{c}_{F_f} \) at the .05 level on a one-tailed test \((T = 38.5, N = 12, \text{giving } z = .04, p < .48)\).

Nursery and Infant Groups Compared

1. Non-verbal score.

The \( F \) scores for the two groups are significantly different for the two groups at the .05 level on a two-tailed test \((U = 54.5, n1 = 13, n2 = 16, \text{on a Mann-Whitney test})\).

None of the remaining scores shows any significant difference between the age groups at the .05 level on two-tailed tests. The calculated value of \( U \) in each
case (with \( n_1 = 13 \) and \( n_2 = 16 \)) is: (2) overt score, \( U = 73 \), (3) covert score, \( U = 66 \), (4) difference between non-verbal and overt score, \( U = 78 \), (5) difference between non-verbal and covert score, \( U = 88.5 \).

The mean values of the \( F \), \( F_o \), and \( F_c \) scores is shown in Fig. 24.

**Discussion**

Hypothesis 1 is strongly confirmed. Both overt and covert self-instructions interfere with the simultaneous conduct of a motor task. This strongly suggests that Meichenbaum and Goodman's results do not really demonstrate the regulatory function of language at all, except in the trivial sense of showing that Ss can obey verbal instructions to tap rapidly. The reason why their Ss were able to tap more rapidly whilst uttering the word 'fast', than when not, was simply because the base line performances did not demand of the Ss that they tap rapidly.

Hypothesis 2 is only extremely weakly supported by the data. There is no significant difference for either age group between the overt and covert conditions. In the older children, however, there is a non-significant trend in the direction of covert responses being accompanied by faster tapping than overt responses. This is shown by the slightly higher mean value of the scores to be seen in Fig. 24. But the differences between the overt and covert conditions are very small
MEAN SCORES ON THE MOTOR TASK OF EXPERIMENT 3

FIG. 2.4
compared with the highly significant differences between either of them and the non-verbal score.

The outcome of Exp. 3, then, does not support the picture of language as a regulator of behaviour. Self-instruction in the task used in the experiment is not even compatible with the maintenance of the same level of performance as when the self-instructions are absent. The relation between the verbal and the motor system that seems most prominent is simply that the verbal responses impose a load on the motor system; in other words they are both competing for the same limited channel capacity. The experiment does not, however, show any significant difference between the overt and covert conditions in the capacity requirements of the verbal responses and so does not provide evidence for the full alternative interpretations of Meichenbaum and Goodman's results which was proposed in the previous discussion.

The objection may be raised, in defence of the regulatory function of language, that it was a foregone conclusion that the motor task would suffer from the extra loading of a simultaneous verbal task. These circumstances, it may be argued, are not appropriate for the regulatory aspects of language to show themselves. What is necessary is to compare the different loadings of self-instructions which are consonant and compatible with the ongoing motor task with the loadings of self-instructions which are incompatible with it. In
In particular this may be investigated in circumstances where Ss are not required to perform a motor task whose proper execution would require all available capacity.

This objection brings out the limitations of Exp. 3. The real significance of language as a factor in the organisation of ongoing motor behaviour may only become apparent when a motor set and a verbal task are pitched directly against one another. Second, Exp. 3 only investigated one end of the spectrum of possible performances of the tapping task. It is not yet known how language would interact with a motor set to tap slowly. In particular it is not known whether differences between overt and covert verbal responses would manifest themselves at the slow end of the spectrum even though they were not significant at the fast end. These issues will be investigated in the next experiment, Exp. 4. (In the statement of the underlying ideas and hypotheses of the next experiment the results of Exp. 3 will be temporarily set aside so that the issues can be stated in a general and unqualified form. The results of the two experiments will then be drawn together and incorporated in the discussion section.)

The next experiment will also provide an opportunity to investigate further the idea that overt and covert responses impose different loads on the motor system.
EXPERIMENT 4. VERBAL SELF-INSTRUCTIONS VERSUS A MOTOR SET

The purpose of the experiment was to examine the role of countermands on a motor set. A countermand is an instruction which runs counter to an ongoing motor task. An example would be saying the words, 'slowly, slowly,...' when one has a set to press a key rapidly. If language has a directive or regulatory function (ignoring for a moment the results of Exp. 3), then a set to tap rapidly (or slowly) would be interfered with by repeated verbalisation of the countermand 'slow' (or 'fast'). Conversely the set would be augmented, or at least maintained, by a self-instruction compatible with the motor set. Three hypotheses will be stated; to preserve symmetry of statement the results of Exp. 3 will not be incorporated into their formulation.

Hypotheses

(1) In a key tapping task repeating the word 'fast' will augment a motor set to tap rapidly and undermine the motor set to tap slowly. Conversely, repeating the word 'slow' will augment the motor set to tap slowly and undermine the motor set to tap rapidly.

(2) In infant school children whispering the self-commands or countermands will augment or undermine the motor performance more strongly than overtly spoken self-instructions (Meichenbaum and Goodman's claim).

On the other hand, from the point of view of the
alternative perspective outlined above the expectation would be that:

(3) Overt verbal tasks performed alongside a motor task will impose a greater load than covert verbal tasks.

No hypotheses will be proposed concerning the number of verbal responses made nor about the relationship of this number to the number of motor responses. The data will be examined to see what relationships emerge empirically.

A more rigorous statement of the hypotheses will be given below. This experiment unambiguously defines for the Ss the motor set that they are to adopt. The strength of the regulatory function of language is tested by seeing if it can overcome this set.

Subjects

The 48 Ss (24 boys, 24 girls) were from the Infirmary Street Primary School and the Milton House Primary School, Canongate, Edinburgh. The Ss were divided into two groups, an Overt group and a Covert group. (The whole of the first group came from the first of the above schools mentioned, but both were similar in atmosphere, classroom regime, and the social composition of their catchment areas.) There were equal numbers of each sex in each group. Table 6 gives the details of the two groups of Ss. No S had to be eliminated from the experiment because of sensory-motor defects or because of unwillingness to cooperate.
Experimental Ss were confined to those of an infant school age because pilot experiments had shown that it was very difficult, given the required experimental design, to get nursery children to complete the necessary number of experimental runs.

### TABLE 6

**Details of the Subjects of Experiment 4**

<table>
<thead>
<tr>
<th>Subject Group</th>
<th>Number</th>
<th>Mean Age in Months</th>
<th>S.D.</th>
<th>Mean Peabody Test Score**</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overt</td>
<td>24*</td>
<td>77.5</td>
<td>9.1</td>
<td>56.1</td>
<td>7.0</td>
</tr>
<tr>
<td>Covert</td>
<td>24*</td>
<td>76.5</td>
<td>6.3</td>
<td>59.6</td>
<td>9.5</td>
</tr>
</tbody>
</table>

* Equal numbers of boys and girls.
** Raw Score. See Appendix I.

**Apparatus**

The apparatus consisted of a morse key clamped to a small table, and a very light, hand-held microphone. Both of these were connected to an oscillograph which recorded each press of the key on one channel and a trace of the spoken input to the microphone on the other channel. For the Covert group, where recording the verbal component of the responses was not feasible, the oscillograph was replaced by the cumulative counter used in the previous experiment.
Experimental Design

Each S was given two test runs of the tapping task with no verbal responses accompanying them. These were to provide a base line for fast and slow tapping rates. The test runs were always given in the same order (fast and then slow) and then four experimental runs were given. In the experimental runs the Ss were placed in turn in each of the following four conditions:

(1) Set to tap rapidly and repeat the word 'fast' (let $F_f$ represent the number of taps produced in this condition).

(2) Set to tap slowly and repeat 'slow' ($S_s$).

(3) Set to tap rapidly and repeat 'slow' ($F_s$).

(4) Set to tap slowly and repeat 'fast' ($S_f$).

Since the above design applies both to the Overt and the Covert group the prefixes 'o' and 'c' have been left out of the symbols; they will only be inserted when it is necessary to differentiate between the two groups. It will be seen that two of the conditions ($F_f$ and $S_s$), are command conditions, and two ($F_s$ and $S_f$), are countermand conditions. The order of the experimental runs was randomised throughout the 24 Ss of each of the two groups, so that every possible order was used within each of the groups.

Given the symbols introduced above, and calling the scores of the test runs $F$ and $S$, the hypotheses can be given a more formal but more thorough statement.
(1) \( P_f > P^* > P_s \) and \( S_f > S > S_s \) for both 'o' and 'e'.

A closely related formulation would be,
\[
(F_f - S_s) > (F - S)^* > (P_s - S_f) \text{ for both 'o' and 'e'.}
\]

(2) \( c^{F_f - o_f} > (o^{F_f - o_f}) \), \( (c^{P_s - o_s}) < (o^{P_s - o_s}) \)
\[
(c^{S_f - o_s} > (o^{S_f - o_s})), (c^{F_f - o_s}) > (o^{F_f - o_s})
\]

(3) \( (F - c^{F_f}) > (F - c^{P_s}) \)
\[
(F - o^{P_s}) > (F - c^{P_s})
\]

**Procedure**

Ss were approached on the same basis as Exp. 3 and introduced to the apparatus in the same way. \( E \) explained that sometimes they would be asked to tap very fast, like this ..., and sometimes very slowly like this .... In this demonstration the fast tapping was at the rate of about 5 taps per sec. and the slow tapping at the rate of about 1 tap per sec. Ss were then asked to try tapping fast, and then, after a few taps to try tapping slowly. This was to ensure that Ss could discriminate properly between fast and slow responses. If there did not appear to be an obvious difference in Ss' rate of tapping in these two tasks they were asked to try again, this time trying to go very fast, and very slow. Very few Ss required this

---

\( \ast \) From Exp. 3 it is known that \( F > F_f, F > P_s, \) etc. This is being ignored at the moment for simplicity.
extra phase of training. No Ss required more than one such extra attempt. When the discrimination had been properly exhibited E explained that he would say 'go' and Ss must tap fast and keep on tapping until he said 'stop' (this was the first test run, F).

On saying 'go', E pressed the start button of the oscillograph and also started a stopwatch. Just prior to saying 'go', E said 'Remember to tap fast'. No more instruction or encouragement was given by E during the 15 sec. run. As in the previous experiment E did not look at S during any of the runs, but looked at the stopwatch. Each run was terminated by 'stop', and the recorder stopped. S was then told, 'Good, you did that nicely', or some other short, generalised indication of approval.

After the second test run, (S), S was shown the microphone and told that it was for talking into. (This part of the procedure obviously only applies to the Overt group.) Ss were then offered the microphone, the offer being directed at the hand that Ss had not selected for the tapping task. They were then told that this time they were to press the key fast (or slow depending on the order of experimental runs to which that had been pre-assigned) and at the same time they were to say, 'fast' (or 'slow') 'in a nice loud voice, over and over again, all the time you are tapping'. E gave a brief demonstration as in Exp. 3. The instruction was repeated and Ss were asked if they
understood. If they hesitated in giving an affirmative reply, or if they looked puzzled or said that they did not understand, the instructions were repeated. This was only necessary about half a dozen times throughout the whole experiment. Given a positive reply S would say, 'Get ready and start when I say go, remember tap fast, and say slow, ... go'. Ss were then taken through the remaining conditions, the task in each case being explained immediately prior to the performance of the task. No demonstration was given before subsequent runs. The gap between each experimental run was about 30 secs. Ss were then thanked and taken back to the classroom after the apparatus had been made ready for the next S. (Only one S confused what she had to say with what she had to do. She was replaced by another female S and is thus not counted amongst the 24 Ss of the Overt group. No S had to be discounted through a reluctance to adopt a normal speaking voice rather than a whisper, or for failing to speak into the microphone. Pilot experiments revealed that these were frequently encountered problems with nursery children performing this experiment, and this fact contributed to the decision to confine this experiment to older children.)

The same procedure was adopted with the Covert group, except, of course, Ss were told to whisper the verbal responses. When E demonstrated what was required prior to the first run the whisper adopted consisted of mouthing the word, and making it just
audible. As regards the Ss, however, no distinction was drawn in this experiment between those who whispered in this fashion and those who whispered in a completely inaudible fashion, perhaps even without lip movements. In the previous experiment Ss were given a very brief training run to check and correct method of whispering; this was dispensed with in this experiment. (In case the status of these undetectable whispers should seem suspicious, being akin to mental events in that they are not observable, the difference between the F and the \( c^F \) and \( c^F_s \) runs will reveal whether the whispers are 'really there' or not, by whether they have any effect, though the problem remains that the number of such responses cannot be checked.)

A few days after the experiment the Ss were given a modified form of the Peabody Test (see Appendix I).

**Scoring**

With the Covert group, scoring simply consisted in reading off the number of motor responses from the counter. With the Overt group scores were read off the two traces on the recording paper coming from the oscillograph. The trace from each motor response was always clear and unambiguous. This was not always the case for the verbal response where there was occasionally the problem of detecting a signal from the background noise. Where the trace was obscure the same criterion was adopted as in Exp. 2.
Results

First of all the motor scores of the Overt group will be analysed, and then the motor scores of the Covert group. Thirdly, these two groups will be compared and contrasted and, fourthly, the verbal responses of the Overt group will be examined.

In all cases, except one, the male and female Ss will be analysed together as there is no significant difference between their scores.

N.B. A purely verbal analysis of the results will be given at the beginning of the discussion section. All the symbols used below are defined on page 114 and in Fig. 25, where the information is presented in graph form.

(1) Overt Group

(i) Comparison of $O_F^f$ and $O_S^f$.

$O_F^f$ is not significantly greater than $O_S^f$ at the .05 level on a one-tailed test ($T = 116.5$, $N = 23$, on a Wilcoxon Test, where $N$ is the number of pairs of scores whose difference is non-zero. This gives $z = -.65$, $p < .26$).

(ii) Comparison of $O_F^f$ and $F$.

$F$ is greater than $O_F^f$ for every S.

(iii) Comparison of $O_S^f$ and $F$.

$F$ is greater than $O_S^f$ for every S.

(iv) Comparison of $S_F^f$ and $S_S^f$.

$S_F^f$ is not significantly greater than $S_S^f$ at the
.05 level on a one-tailed test ($T = 96.5$, $N = 22$, $z = -.96$, $p < .17$).

(v) Comparison of $S_f$ and $S$.

$S_f$ is not significantly greater than $S$ at the .05 level on a one-tailed test ($T = 90.5$, $N = 21$, $z = .85$, $p < .20$).

(vi) Comparison of $S_s$ and $S$.

$S$ is not significantly greater than $S_s$ at the .5 level on a one-tailed test ($T = 73.5$, $N = 21$, $z = -1.44$, $p < .07$).

(vii) Comparison of $(S_f - S_s)$ and $(S_f - S_f)$.

$(S_f - S_s)$ is not significantly greater than $(S_f - S_f)$ at the .05 level on a one-tailed test ($T = 91$, $N = 23$, $z = -1.4$, $p < .08$).

(viii) Comparison of $(F - S)$ and $(S_f - S_s)$ and $(S_f - S_f)$.

$(F - S)$ can be compared to the maximum of the other two scores in a matched pairs test. It is found that $(F - S)$ is significantly greater than the maximum of these two conditions at the .01 level on a two-tailed test ($T = 6.5$, $N = 24$).

(ix) Comparison of fast and slow responses within the non-verbal, command and countermand conditions.

In each case a significant discrimination was maintained.

(a) Non-verbal: $F$ is greater than $S$ for every $S$.

(b) Command: $S_f$ is significantly greater than $S_s$ at the .005 level on a one-tailed test ($T = 9.5$, $N = 24$).
Countermand: $c^F_S$ is significantly greater than $c^S_f$ at the .005 level on a one-tailed test ($T = 48.5, N = 24$).

Fig. 25 shows the mean values, for the 24 $S$s in the Overt condition, of the scores analysed above.

(2) Covert Group

(i) Comparison of $c^F_f$ and $c^F_S$.

$c^F_f$ is significantly greater than $c^F_S$ at the .025 level on a one-tailed test ($T = 65, N = 22$).

(ii) Comparison of $c^F_S$ and $F$. $F$ is greater than $c^F_f$ for every $S$ but one, where $F = c^F_f$.

(iii) Comparison of $c^S_f$ and $F$. $F$ is greater than $c^S_f$ for every $S$.

(iv) Comparison of $c^S_f$ and $c^S_S$.

(a) $c^S_f$ is not significantly greater than $c^S_S$ at the .05 level on a one-tailed test ($T = 81, N = 21, z = -1.2, p < .12$).

(b) If, however, only the female $S$s are considered, then $c^S_f$ is significantly greater than $c^S_S$ at the .01 level on a one-tailed test ($T = 5, N = 10$).

(v) Comparison of $c^S_f$ and $S$. $c^S_f$ is not significantly greater than $S$ at the .05 level on a one-tailed test ($T = 124, N = 22, z = -1.2, p < .45$).

(vi) Comparison of $S_S$ and $S$. $S$ is not significantly greater than $c^S_S$ at the .05
level on a one-tailed test \( T = 56, N = 19, z = -1.57, p < .06 \).

(vii) Comparison of \( (c^F_f - c^S_S) \) and \( (c^F_S - c^S_f) \).

\( (c^F_f - c^S_S) \) is significantly greater than \( (c^F_S - c^S_f) \), at the .01 level on a one-tailed test \( T = 61.5, N = 24 \).

(viii) Comparison of \( (F - S) \) and \( (c^F_f - c^S_S) \) and \( (c^F_S - c^S_f) \).

As with the Overt group, \( (F - S) \) can be compared with the maximum of the command and countermand differences. It is found that \( (F - S) \) is significantly greater than the maximum of either of these two at the .01 level on a two-tailed test \( T = 1.5, N = 23 \).

(ix) Comparison of fast and slow responses within the non-verbal, command and countermand conditions.

In each case a significant discrimination was always maintained.

(a) Non-verbal: \( F \) is greater than \( S \) for every \( S \).

(b) Command: \( c^F_f \) is greater than \( c^S_S \) for every \( S \).

(c) Countermand: \( c^F_S \) is greater than \( c^S_f \) for every \( S \) except two. \( c^F_S \) is significantly greater than \( c^S_f \) at the .005 level on a one-tailed test \( T = 1, N = 23 \).

Fig. 25 shows the mean values, for the 24 \( S_E \) in the Covert condition, of the scores analysed above.
(3) **Comparison of Overt and Covert Groups**

(i) **Comparison of** \((\text{o}_F^p - \text{o}_S^p)\) **and** \((\text{o}_F^o - \text{o}_S^o)\).

\((\text{o}_F^p - \text{o}_S^p)\) **is not significantly greater than** \((\text{o}_F^o - \text{o}_S^o)\) **at the .05 level on a one-tailed test.** On a Mann-Whitney test \(z = .29, p < .39\).

(ii) **Comparison of** \((\text{o}_S^p - \text{o}_S^p)\) **and** \((\text{o}_S^o - \text{o}_S^o)\).

\((\text{o}_S^p - \text{o}_S^p)\) **is not significantly greater than** \((\text{o}_S^o - \text{o}_S^o)\) **at the .05 level on a one-tailed test,** \(z = .19, p < .42\).

(iii) **Comparison of** \((\text{o}_F^p - \text{o}_S^o)\) **and** \((\text{o}_F^o - \text{o}_S^p)\).

\((\text{o}_F^p - \text{o}_S^o)\) **is significantly greater than** \((\text{o}_F^o - \text{o}_S^p)\) **at the .01 level on a one-tailed test,** \(z = 2.48, p < .007\).

(iv) **Comparison of** \((\text{o}_S^p - \text{o}_S^o)\) **and** \((\text{o}_S^o - \text{o}_S^o)\).

\((\text{o}_S^p - \text{o}_S^o)\) **is not significantly greater than** \((\text{o}_S^o - \text{o}_S^p)\) **at the .05 level on a one-tailed test,** \(z = 1.5, p < .07\).

(v) **Comparison of** \((\text{o}_F^o - \text{o}_F^p)\) **and** \((\text{o}_F^o - \text{o}_F^p)\).

\((\text{o}_F^o - \text{o}_F^p)\) **is significantly greater than** \((\text{o}_F^o - \text{o}_F^p)\) **at the .01 level on a one-tailed test,** \(z = 2.44, p < .007\).

(vi) **Comparison of** \((\text{o}_F^o - \text{o}_F^o)\) **and** \((\text{o}_F^o - \text{o}_F^o)\).

\((\text{o}_F^o - \text{o}_F^o)\) **is not significantly greater than** \((\text{o}_F^o - \text{o}_F^o)\) **at the .05 level on a one-tailed test,** \(z = 1.58, p < .06\).
MEAN SCORES ON THE MOTOR TASKS OF EXPERIMENT 4

FIG. 2.5
(4) **Examination of the Number of Verbal Responses**

This only applies to the Overt response group. The tests are to see if there are any correlations between the numbers of verbal and motor responses in the various conditions. In one case, which will be important later on, the comparison will be between the number of verbal responses made in two conditions.

(i) Number of verbal and motor responses in the $F_r$ condition.

Calculating Spearman's Rank Correlation Coefficient gives $r_s = .28$. This is not significant at the .1 level on a two-tailed test.

(ii) Number of verbal and motor responses in the $F_s$ condition.

$r_s = .59$, which is significant at the .02 level on a two-tailed test.

(iii) Number of verbal and motor responses in the $S_r$ condition.

$r_s = -.48$, which is significant at the .1 level on a two-tailed test, but not at the .05 level.

(iv) Number of verbal and motor responses in the $S_s$ condition.

$r_s = -.33$, which is not significant at the .1 level on a two-tailed test.

(v) Comparison of number of verbal responses in $oF_r$ and $oF_s$ conditions.

There is no significant difference at the .05 level on a two-tailed test between these conditions ($U = 275$, $z = -.25$, $p < .8$).
Discussion

First, the large quantity of data analysed above will be simplified by sifting out some empirical regularities. The results, as they apply to the Overt and Covert groups separately, can be summed up in three generalisations per group.

Overt Group

(1) Ss can maintain a discrimination between fast and slow responses regardless of whether they are overtly telling themselves what to do or the opposite of what they are to do. In the non-verbal condition, however, this discrimination is better, i.e. F - S is larger, than in either the command or countermand conditions, which do not differ significantly.

(2) If Ss overtly tell themselves what to do, this does not significantly affect performance compared with telling themselves the opposite of what they are to do. That is, saying 'fast' does not make Ss tap faster than saying 'slow', and this regardless of whether the task is rapid or slow tapping.

(3) The outstanding fact, though, is that saying either 'fast' or 'slow' slows down the task of rapid tapping very significantly. It does not, however, affect the task of slow tapping.

The corresponding three generalisations for the Covert group are, in a number of respects, very different.
Covert Group

(1) Ss can maintain a discrimination between fast and slow responses regardless of whether they are covertly telling themselves what to do or the opposite of what they are to do. In the non-verbal condition this discrimination is at its greatest, and significantly greater than in the command condition. This, in turn, is significantly larger than in the countermand condition.

(2) Covertly saying 'fast' is associated with faster tapping than when Ss are covertly saying 'slow'. This applies to the task of rapid tapping, and also, in the case of the group of female Ss, for slow tapping.

(3) Again, covertly saying either 'fast' or 'slow' significantly slows down the rate of rapid tapping. Slow tapping is not affected.

The relationship between the Overt and the Covert groups can be summed up in two generalisations.

Overt and Covert Groups Compared

(1) In the Covert case discrimination between fast and slow responses, when Ss are telling themselves what to do (command condition), is significantly greater than this discrimination in the Overt case for the command condition. This discrimination is not significantly different as between Overt and Covert Ss in the countermand condition.
(2) The difference between the rate of non-verbal fast tapping and the rate accompanied by the word 'fast' (command condition) is considerably greater for the Overt case than for the Covert case. There is no corresponding difference in the countermand case.

The only generalisation that seems possible about the relationship between the number of Overt verbal responses and the number of taps made is that there is no strong correlations between these numbers. There are significant correlations when the verbal response does not correspond to the motor task, i.e. in the countermand conditions, but not in the command conditions.

These empirical generalisations are stated in theoretically neutral terms, so that no contentious theory is presupposed in their formulation. The methodological importance of this approach has already been brought out.

Now that the results have been formulated as a number of empirical generalisations their bearing on the hypotheses behind the experiment will be stated explicitly. Finally the theoretical significance of the results will be explored.

Hypothesis (1): This hypothesis concerns the basic claim that motor responses will be influenced in the direction of the self-generated verbal instructions. In the non-verbal condition this hypothesis is clearly
false. The non-verbal condition does not produce a score which is mid-way between the command and countermand conditions. In this respect Exp. 4 strongly bears out Exp. 3. But putting aside the non-verbal condition, which clearly does not fit in with the simple regulatory hypothesis, what about the relations between the command and countermand conditions? The hypothesis is true for the Covert group in the fast tapping task and applies also to the distinction between fast and slow tapping. Thus it is true that,

\[ c_F^f > c_F^s \quad \text{and} \quad (c_F^f - c_S^s) > (c_F^s - c_S^f) \]

but all other parts of the hypothesis are false.

Hypothesis (2): This hypothesis claims greater regulatory control for covert than overt verbal responses. Only one part of this hypothesis is correct; that is,

\[ (c_F^f - c_S^s) > (c_F^s - c_S^f) \]

Hypothesis (3): This concerns the relative decline in the rate of rapid tapping when accompanied by overt and covert responses. Only one part of it – but an important part – is supported by the experiment; that is,

\[ (F - c_F^f) > (F - c_F^o) \]

The picture that emerges is a complex but interesting one. It seems that the experimental results do provide some support for the Meichenbaum and Goodman and Luria picture, and for what might be called
the 'load hypothesis', which denies a regulatory function for language.

The load hypothesis sees the verbal system as merely competing for capacity with the motor system and accounts for Meichenbaum and Goodman's results by postulating a greater loading associated with overt than covert responses at the age considered. The lapse from the non-verbal rate of rapid tapping to verbally accompanied rapid tapping is a rough but plausible index of the loading of the verbal responses. Given this, then Exp. 4 establishes that overt utterance of the word 'fast', along with fast tapping, imposes a greater load than covert utterance of the same word.* Reinforcing this fact there is also considerable evidence to support the claim that overt utterances have no regulatory function at all in the conditions investigated.

All of this fits in well with the load hypothesis. However, there is also some evidence which does not fit in neatly with this view. For example, there appear to be aspects of the covert responses which influence the motor performance and which are not explicable by simple considerations of capacity. On the view that capacity alone was relevant it would be expected that

\[ c^Pf = c^Ps \]

when in fact it has been established that

\[ c^Pf > c^Ps \]

So it appears that the covert verbal production of the words 'slow' and 'fast' in fact make a difference to the

* There might, of course, simply be fewer covert responses.
rate of fast tapping. These results represent the first really plausible example of the regulatory function of language found in this study, though an alternative explanation still presents itself. This is that there happened to be a greater number of covert verbal responses of the word 'slow' than of the word 'fast', thus explaining in capacity terms how the word appears to regulate the motor responses. But the analysis of the overt verbal responses showed that there was no significant difference between the number of utterances of the words 'fast' and 'slow' and it is plausible to assume the same for the covert responses. Experimental support for this assumption is provided by Landauer (1962). These features of the results, then, indicate a regulatory function for language.

There is a further line of development of the capacity explanation of the results still to be explored. The experimental data may perhaps be explained if the notion of the capacity of a verbal response is refined by introducing the idea of the 'compatibility' of two responses. If two responses are incompatible they will be difficult to perform together, and hence require more channel capacity. (This idea of compatibility is akin to that developed by Pitts and Seeger (1953) to describe S-R relationships. Perhaps uttering the word 'slow', given the set to tap rapidly, is a demand to perform incompatible responses. The result that \( c_F^p > c_F^s \) would then be explained. But then this theory would
have to explain why it was not the case that $o^f \geq o^s$.

A further refinement would be required to the effect that the different loadings due to incompatibility only become apparent when not masked by the loadings associated with the mode of delivery of the responses, viz. overt or covert. Since the overt responses have greater loading than covert responses then the differences between the command and countermand cases will show up less. This theoretical position could also be supported by the belief that the loadings of verbal responses, whatever their source, can only impose up to a certain limit on the motor system, thus indicating some built-in distribution of capacity to different response modalities.

The load hypothesis can maintain itself, then, given the two subsidiary hypotheses of (a) incompatibility, and (b) the complementary nature of the loadings from incompatibility and loudness of verbal response. But apart from the manifestly ad hoc character of (b) criticisms can be levelled against (a). For example, the origin of the postulated incompatibility must be explained. To assert that saying 'slow' is incompatible with rapid tapping is, perhaps, to accept tacitly that the meaning of a verbal response is crucial when considering how it impinges on a motor task. But surely the relevance of the meaning of the verbal responses indicates that the very organisation of the motor acts must involve a verbal element. If this were
not the case it is difficult to see how meanings would be a factor in determining how much the verbal responses would interfere. (This is another form of the plausible metaphysical principle that likes can only interact with likes, hence meanings can only interfere with meanings.) This line of criticism certainly seems cogent, at least in as far as the notion of incompatibility in this case obviously opens the door to an explanation in terms of the very regulatory thesis that it was designed to exclude.

In summary, then, the outcome of Exps. 3 and 4 is this:

(1) Meichenbaum and Goodman seem to be justified in asserting that language does show a regulatory function in the sort of tasks investigated. Although their experiments are capable of explanation without appeal to regulatory hypotheses this does not seem to apply to the further data gathered above.

(2) The examples of language exerting a regulatory influence that have been found occur for covert but not for overt responses. This too bears out Meichenbaum and Goodman's claim. (Unfortunately because the area of conflict of the regulatory and capacity theories is in the realm of covert responses the rival claims regarding the number of such responses is not in practice decidable in the context of Exp. 4.)

(3) Although the claim that language has a regulatory function is very plausible, it seems to be what may be
called a 'second order effect'. The most significant result of introducing language is to interfere with the performance of motor tasks if these in any way tax the capacity of the Ss. The interference, however, in some circumstances varies in a way which seems to depend on the meanings of the words used in the verbal responses.

This conclusion, that the regulatory function of language is a second order effect, is of both practical and theoretical significance. It indicates that in the sort of situation investigated, the benefits of using language to regulate behaviour are outweighed by the disadvantages of its interfering influence. Theoretically this indicates that the experimental situations just investigated may not be revealing the primary and most important modes of interaction between speech and action. The two systems obviously do have significant interconnections, but these do not seem to have been tapped by the above experimental approach. The only really strong forms of regulation that come out in these experiments are concerned with providing the initial motor set. There do not seem to be important verbal elements within the organisation of the ongoing motor acts in the cases considered. In retrospect this is perhaps not too surprising. The motor tasks involved are repetitive and 'ballistic' in nature. They lack the internal structuring which could indicate the existence of verbal elements in the organisation of a motor act. Indeed this line of thought could provide a
clue to understanding why the observed degree of linguistic regulation was there at all, but yet so very small and residual. It could be hypothesised that in the cases investigated in the last two experiments the verbal system could gain no real purchase on the internal organisation of the motor acts but was having a residual effect on such factors as motivation and attention to the goal of the activity. To maintain a fast tapping rate for 15 secs. requires considerable effort and is the sort of task where encouragement would seem to pay dividends. Repeating the words 'fast' or 'slow' to oneself could act as a form of encouragement (for fast or slow tapping respectively). It might be expected to have a slight regulatory influence by influencing the set of the $S$ even if it did not impinge on the actual organisation of the responses. To adopt terms like 'encouragement' in an explanation is not wholly satisfactory; but it does at least indicate that the point of action of the observed regulatory influence may be found in factors external to the actual organisation of the motor acts, that is, in the factors which determine the manner of execution of the acts.

In the light of these theoretical discussions the next experiment will be concerned with an experimental situation in which the motor tasks involve a considerable element of what has been termed 'structuring'. That is: the tasks will require a motor response which involves the discrimination of stimuli, their categorisation,
and then decision processes for the selection of the appropriate response. These decisions will require the application of simple rules which link the stimulus and response.
CHAPTER III

AN EXPERIMENTAL TEST OF A.R. LURIA'S THEORY OF VERBAL SELF-REGULATION

The discussion of the two previous experiments suggested that the sort of task in which the regulatory function of language might reveal itself was one which involved (a) the discrimination and categorisation of stimuli, and (b) decision processes in which the response is selected from some relevant ensemble. There is a sense in which all behaviour may be said to involve these features, but it is also clearly possible to devise situations in which categorisation and decision processes play a more prominent role than in the simple tapping tasks of the last two experiments. Two experiments of the required sort will now be introduced via a brief reconsideration of the first principles of Luria's theory as it was formulated at the end of Chap. I.

Introduction to Experiments 5 and 6

For Luria the verbal system is involved in the organisation of motor acts because it provides a source of overt or covert verbal self-instructions. Roughly a child does something by first saying something. Suppose that a S is presented with a sequence of red and blue light signals and told to press a blue button when a red light comes on and vice versa. The subsequent behaviour has for Luria the following structure:
First there will be a verbal analysis of the stimulus, is it red or blue? A covert process of labelling will take place. Then will come the verbal organisation of the motor act, having the form of a self-instruction, perhaps, 'if see red press blue', or 'red so blue'. (Compression and simplification would be expected from Vygotsky's work on inner speech.)

On the basis of this account the following predictions can be made. Suppose that a S is given a task which involves both motor responses and overt verbal responses. Suppose further that an overt verbal output is demanded which is directly counter to the postulated self-instructions, then, at the very least, an attenuation of the self-instructions might be expected. Under these circumstances the control of the motor responses should decline with the intrusion of responses evoked by the overt counter instructions.

Thus, the following hypotheses can be stated:

**Hypotheses**

(1) Motor responses conjoined with compatible overt self-instructions should be performed more accurately than motor responses conjoined with incompatible overt self-instructions.

Adding to this the Iuria thesis that, except in very young children, the verbal system is more developed and flexible than the motor system, then there should be a greater tendency for the motor system to accommodate
Itself to the verbal system than vice versa, thus:

(2) Where the verbal system and the motor system are in competition then the verbal system will predominate over the motor system. Ss will tend to do what they say rather than say what they do.

The above argument leading to these hypothesis is in fact only a sketch: the full deduction is given in Appendix II. The hypotheses also need stating more precisely; this will be done after describing an experimental situation in which they can be tested.

The basic experimental procedure is common to Exps. 5 and 6 which differ mainly in the load imposed on Ss as measured by speed of presentation of stimuli. For this reason the results of both experiments will be discussed together after Exp. 6.

EXPERIMENT 5. COMPATIBLE AND INCOMPATIBLE SELF-INSTRUCTIONS IN A SENSORY-MOTOR TASK

Design

Ss were presented with a predetermined sequence of light signals, some red, some blue. They were asked to press one of two coloured buttons, one red, one blue, in response to each signal. At the same time as pressing the button the Ss had to make an overt verbal response, uttering the word 'red' or 'blue', depending on the colour of the light and the experimental condition. There were four experimental conditions, which are indicated below in Table 7.
TABLE 7
Experimental Conditions for Experiment 5

<table>
<thead>
<tr>
<th>Condition</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour of Stimulus</td>
<td>Red</td>
<td>Blue</td>
<td>Red</td>
<td>Blue</td>
</tr>
<tr>
<td>Light</td>
<td>Blue</td>
<td>Red</td>
<td>Blue</td>
<td>Red</td>
</tr>
<tr>
<td>Required Button</td>
<td>Red</td>
<td>Blue</td>
<td>Red</td>
<td>Blue</td>
</tr>
<tr>
<td>Press</td>
<td>Blue</td>
<td>Red</td>
<td>Blue</td>
<td>Red</td>
</tr>
<tr>
<td>Required Verbal</td>
<td>Red</td>
<td>Blue</td>
<td>Blue</td>
<td>Red</td>
</tr>
<tr>
<td>Response</td>
<td>Red</td>
<td>Blue</td>
<td>Blue</td>
<td>Red</td>
</tr>
<tr>
<td>Compatibility</td>
<td>Compatible</td>
<td>Incompatible</td>
<td>Incompatible</td>
<td>Compatible</td>
</tr>
</tbody>
</table>

Note on Terminology

For the sake of brevity these experimental conditions will, from now on, simply be referred to by their number, viz. condition 2, and no further description of them will usually be given other than the occasional reminder of whether they are compatible or incompatible conditions. Reference back to the above table may be useful in following the argument. When a condition is referred to simply as 'compatible' or 'incompatible' this will refer to the relationship between the motor and verbal responses. In the discussion section a further notion of compatibility will emerge in which it refers to S-R relationships. Except when the context makes the meaning quite clear it will always be made explicit if
this second sense is intended.

Each S was given all four experimental conditions after reaching criterion in a trial run for that condition. Condition 1 was always given first, after which came conditions 2, 3 and 4, whose order was randomised across Ss. Finally condition 1 was re-run. Four Ss, 2 male and 2 female, were given each of the 6 possible orders in which the experimental conditions could be arranged on the above design.

Subjects

The 24 Ss were drawn from the Sciennes School, Edinburgh. The Ss were the final 24 pupils on the register list of one of the classes. The first half-dozen pupils on the register had taken part in the pilot experiments. No S was reported by their teacher as having sensory-motor defects, and no S had to be eliminated because of unwillingness to cooperate in the experiment. Table 8 gives details of the S's ages and scores on a modified Peabody Picture Vocabulary Test.

**TABLE 8**

<table>
<thead>
<tr>
<th>Subject Group</th>
<th>Number</th>
<th>Mean Age in Months</th>
<th>S.D.</th>
<th>Mean Peabody Score</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>12</td>
<td>85.2</td>
<td>2.4</td>
<td>61.6</td>
<td>8.7</td>
</tr>
<tr>
<td>Female</td>
<td>12</td>
<td>84.4</td>
<td>3.0</td>
<td>62.5</td>
<td>9.4</td>
</tr>
</tbody>
</table>

* Raw Score. See Appendix I.
Apparatus

The general layout of the apparatus is given in Fig. 26. It consisted of (i) a device which could produce a sequence of light signals which could be repeated for each S, and (ii) a stimulus-response unit containing the stimulus lights and the response buttons, plus (iii) a means of recording both the stimuli and the responses. The exact form of the S-R unit is also shown below. The light signals were generated by two tones on a magnetic tape which actuated voice keys. The stimuli and motor responses were recorded on a pen recorder. The verbal responses were recorded by E.

Stimuli

The stimulus material consisted in the following sequence of 10 blue (B) and 10 red (R) light signals. Each light flash lasted 1.0 sec. and the interval between successive stimuli was 2.0 secs.

BBRBBRBBBRRBBBRRBBRBR

The sequence was preceded by a marker on the magnetic tape which was aligned with a mark on the tape recorder and which indicated that the first light signal of the sequence would begin in 3 secs. The marker did not trigger the lights but was used by E so that there was a constant time between his switching on the apparatus and the first stimulus.
(a) General layout of the apparatus for experiment 5.

(b) Details of stimulus-response unit (not to scale).

Fig. 2.6
Procedure

Ss were taken by E from their classroom to one nearby which housed the apparatus. They were then seated at a table with E next to them and shown the stimulus lights and response buttons. Whilst operating the lights manually E explained that 'every time the red light comes on (flash red light) I want you to press the red button and say "red!" in a nice loud voice...like this (E demonstrates)...and every time the blue light comes on press the blue button and say "blue!"...' (E again demonstrates). S was then invited to try and E manually produced the test sequence R B R R B B. The sequence was repeated until S could produce one complete set of motor and verbal responses for the sequence. The speed of presentation of the test was approximately that used during an experimental run, the first of which was then presented.

Ss were told that the machine that they could see would switch the lights on and off to save E the trouble and they were to do just what they had been doing. E reminded S of the instructions and switched on the pen recorder and then the tape recorder to work the lights. As the tape recorder was switched on the S was told, 'get ready!' E recorded Ss' verbal responses on a checklist noting against each light signal whether the verbal response was R or B. During the experimental runs E did not look at S in order that S would not be distracted. When the sequence was complete and the
apparatus switched off the S was told that he had done well and that something different would now be tried. E then adjusted the tape recorder to ensure that the marker for the next run was in place and then demonstrated the next set of stimuli and responses. Apart from appropriate substitutions the presentation of the instructions and the test sequence was exactly the same from run to run, and the instructions were always repeated immediately before each run.

On completion of all of the experimental conditions the Ss were thanked and returned to the classroom. The total time for the experiment varied from 3 to 5 depending on the amount of practice required, but was in the region of 10 minutes. Most Ss needed only one or two test runs and none more than half a dozen.

On only 5 out of a total of 120 individual experimental runs did Ss become muddled as soon as the light sequence started, i.e. making no responses and telling E that they had forgotten the instructions. On two other runs Ss stopped responding in the middle of a sequence and announced that they had forgotten what to do. In these circumstances the sequence was immediately stopped, the Ss reassured and the training sequence and instructions for the relevant run repeated. Only one S produced more than one interruption and on both occasions it was at the beginning of a run before any responses had been made. In none of the cases was the S discarded. In view of the complexity of the experimental task it
was perhaps surprising that there were not significantly more cases like this.

One final detail of procedure concerns the use of the preferred hand for button pressing. If Sa tended to use both hands in the motor task they were asked to press with only one hand, keeping the other in their lap. If they seemed undecided as to which hand to use they were told to use the hand that they write with. In the experimental runs Sa occasionally resorted to using one hand for each button. Sa were not stopped in mid run from doing this but were gently reminded during the next test sequence to use only one hand.

**Scoring Criterion**

A motor response was defined as a button press sufficient to cause deflection of the pen recorder. The pen recorder was so arranged that it recorded only two signal values, on or off. A deflection in one direction indicated that the blue button had been pressed, one in the other direction that the red button had been pressed. A similar on/off arrangement applied to the recording of the red and blue lights.

Any response trace which began after the onset of a stimulus trace, and before or at the beginning of the next stimulus trace, was deemed a response to the first stimulus. The very occasional second extra responses to a stimulus was ignored.

As indicated earlier verbal responses were recorded
by E. Here again second responses were ignored. Thus corrections like, 'red...no! blue', were counted as red, though the occasional 'r...blue!' was counted as blue. In no case was E aware that a verbal response had been made which could not be clearly discriminated as 'red' or 'blue'.

Ignoring extra responses, which previous work has shown to be both rare and unrevealing, there are three important classes of response:

1. (C) correct responses, whether motor or verbal;
2. (I) intrusions of opposite motor or verbal responses;
3. (M) missing motor or verbal responses.

This classification now permits a clearer statement of the hypotheses to be tested.

Restatement of Hypotheses

Remember that experimental conditions 1 and 4 are such that the motor and verbal responses are compatible with one another whereas in conditions 2 and 3 they are incompatible. The first hypothesis then breaks down into three parts.

---

* It is legitimate to criticise this method of recording responses because of its lack of objectivity. Originally the apparatus had been designed to record a trace of the verbal response and this would have provided at least a partial check. It transpired, however, that the sensitivity of the microphone could not be adjusted to capture all the verbal responses without recording a great deal of extraneous noise. In pilot experiments Ss' verbal responses had also been recorded on a tape recorder which enabled E to check the accuracy of his own records. Since there was complete agreement between E's records and the tapes this further check was also discarded, to simplify the conduct of the experiment.
(1.1) The combined number of correct motor responses of conditions 2 and 3 will be less than the combined number of correct responses of conditions 1 and 4.

(1.2) The combined number of missing motor responses in conditions 2 and 3 will be greater than the combined number of missing motor responses in conditions 1 and 4.

(1.3) The combined number of intrusive (opposite) motor responses in conditions 2 and 3 will be greater than the combined number of intrusive motor responses in conditions 1 and 4.

The second hypothesis becomes:

(2) The combined number of intrusive (opposite) motor responses in conditions 2 and 3 will be greater than the combined number of intrusive verbal responses in conditions 2 and 3.

The results of Exp. 5 will now be analysed. The analysis will be taken further than is required for merely judging the above hypotheses. This is to provide extra material that will be used in the discussion section that will follow the account of Exp. 6.

Results

The graphs below give the mean motor and verbal scores for the various experimental conditions.
FIG. 2.7

FIG. 2.8
MEAN NUMBER OF INTRUSIVE (OPPOSITE) MOTOR RESPONSES

FIG. 29

MEAN NUMBER OF CORRECT VERBAL RESPONSES

FIG. 30
MEAN NUMBER OF MISSING VERBAL RESPONSES

FIG. 31

MEAN NUMBER OF INTRUSIVE (OPPOSITE) VERBAL RESPONSES

FIG. 32
To test Hypothesis 1 the combined motor scores in conditions 2 and 3 are compared to the combined motor scores in conditions 1 and 4.

**TABLE 9**
Combined Motor Scores in Conditions 1 and 4 compared with Combined Motor Scores in Conditions 2 and 3 of Experiment 5

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>$T = 18.5$ (NS)</td>
<td>$T = 14.5$ (NS)</td>
<td>$T = 18.5$ (NS)</td>
</tr>
<tr>
<td></td>
<td>$N = 11$</td>
<td>$N = 10$</td>
<td>$N = 10$</td>
</tr>
<tr>
<td>Female</td>
<td>$T = 19.5$ (NS)</td>
<td>$T = 5.0^*$</td>
<td>$T = 21$ (NS)</td>
</tr>
<tr>
<td></td>
<td>$N = 11$</td>
<td>$N = 11$</td>
<td>$N = 9$</td>
</tr>
<tr>
<td>Combined</td>
<td>$T = 70.5$ (NS)</td>
<td>$T = 34.5^*$</td>
<td>$T = 81$ (NS)</td>
</tr>
<tr>
<td></td>
<td>$N = 22$</td>
<td>$N = 21$</td>
<td>$N = 19$</td>
</tr>
</tbody>
</table>

$^*$ Sig. at .005 level on a one-tailed Wilcoxon Test.

**TABLE 10**
Comparison of Motor Scores in Conditions 1 and 2 of Experiment 5

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>$T = 3^*$</td>
<td>$T = 2^*$</td>
<td>$T = 15$ (NS)</td>
</tr>
<tr>
<td></td>
<td>$N = 12$</td>
<td>$N = 11$</td>
<td>$N = 11$</td>
</tr>
<tr>
<td>Female</td>
<td>$T = 13.5$ +</td>
<td>$T = 12$ +</td>
<td>$T = 3.5$ (NS)</td>
</tr>
<tr>
<td></td>
<td>$N = 12$</td>
<td>$N = 12$</td>
<td>$N = 4$</td>
</tr>
<tr>
<td>Combined</td>
<td>$T = 27^*$</td>
<td>$T = 25.5^*$</td>
<td>$T = 30$ (NS)</td>
</tr>
<tr>
<td></td>
<td>$N = 24$</td>
<td>$N = 23$</td>
<td>$N = 15$</td>
</tr>
</tbody>
</table>

$^*$ Sig. at .005 level on a one-tailed Wilcoxon Test.
### TABLE 11
Comparison of Motor Scores in
Conditions 1 and 3 of Experiment 5

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 8.5*</td>
<td>T = 23 (NS)</td>
<td>T = 3.5 +</td>
</tr>
<tr>
<td></td>
<td>N = 12</td>
<td>N = 10</td>
<td>N = 9</td>
</tr>
<tr>
<td>Female</td>
<td>T = 2.5*</td>
<td>T = 4*</td>
<td>T = 0*</td>
</tr>
<tr>
<td></td>
<td>N = 11</td>
<td>N = 10</td>
<td>N = 8</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 17*</td>
<td>T = 47.5 +</td>
<td>T = 4*</td>
</tr>
<tr>
<td></td>
<td>N = 23</td>
<td>N = 20</td>
<td>N = 17</td>
</tr>
</tbody>
</table>

* Sig. at .01 level on a one-tailed Wilcoxon Test.
** Sig. at .005 level on a one-tailed Wilcoxon Test.

To test Hypothesis 2 the motor intrusions are compared with the verbal intrusions in conditions 2 and 3.

### TABLE 12
Comparison of the Motor and Verbal Scores when Conditions 2 and 3 of Experiment 5 are Combined

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 8.5 (NS)</td>
<td>T = 18 (NS)</td>
<td>T = 0*</td>
</tr>
<tr>
<td></td>
<td>N = 10</td>
<td>N = 10</td>
<td>N = 9</td>
</tr>
<tr>
<td>Female</td>
<td>T = 25.5 (NS)</td>
<td>T = 8 (NS)</td>
<td>T = 22 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 10</td>
<td>N = 5</td>
<td>N = 9</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 73.5 (NS)</td>
<td>T = 44.5 (NS)</td>
<td>T = 44.5 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 20</td>
<td>N = 15</td>
<td>N = 18</td>
</tr>
</tbody>
</table>

* Sig. at .005 level on a one-tailed Wilcoxon Test.
Comparison of the motor scores on runs 2, 3 and 4.

**TABLE 13**

Comparison of Motor Scores in Conditions 2 and 4 of Experiment 5

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 15 (NS)</td>
<td>T = 13 (NS)</td>
<td>T = 12 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 12</td>
<td>N = 7</td>
<td>N = 11</td>
</tr>
<tr>
<td>Female</td>
<td>T = 13.5 (NS)</td>
<td>T = 6+</td>
<td>T = 3 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 10</td>
<td>N = 9</td>
<td>N = 7</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 73 (NS)</td>
<td>T = 37.5 (NS)</td>
<td>T = 25.5$^{H}$</td>
</tr>
<tr>
<td></td>
<td>N = 22</td>
<td>N = 16</td>
<td>N = 18</td>
</tr>
</tbody>
</table>

$^{H}$ Sig. at .01 level on a two-tailed Wilcoxon Test.

$^{+}$ At .05 level.

**TABLE 14**

Comparison of Motor Scores in Conditions 3 and 4 of Experiment 5

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 2$^{H}$</td>
<td>T = 6+</td>
<td>T = 17 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 11</td>
<td>N = 11</td>
<td>N = 9</td>
</tr>
<tr>
<td>Female</td>
<td>T = 17.5 (NS)</td>
<td>T = 22 (NS)</td>
<td>T = 19.5 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 10</td>
<td>N = 10</td>
<td>N = 9</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 50$^{HN}$</td>
<td>T = 80 (NS)</td>
<td>T = 74.5 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 21</td>
<td>N = 21</td>
<td>N = 18</td>
</tr>
</tbody>
</table>

$^{HN}$ Sig. at .01 level on a two-tailed Wilcoxon Test.

$^{+}$ At .02 level.

$^{*}$ At .05 level.
The motor responses in the compatible runs will now be compared to one another.

**TABLE 15**

*Comparison of Motor Scores in Conditions 1 and 4 of Experiment 5*

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 0&lt;sup&gt;+&lt;/sup&gt;</td>
<td>T = 4&lt;sup&gt;+&lt;/sup&gt;</td>
<td>T = 0&lt;sup&gt;+&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>N = 12</td>
<td>N = 10</td>
<td>N = 10</td>
</tr>
<tr>
<td>Female</td>
<td>T = 1&lt;sup&gt;+&lt;/sup&gt;</td>
<td>T = 14.5 (NS)</td>
<td>T = 15&lt;sup&gt;++&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>N = 10</td>
<td>N = 8</td>
<td>N = 7</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 2&lt;sup&gt;+&lt;/sup&gt;</td>
<td>T = 94 (NS)</td>
<td>T = 2&lt;sup&gt;+&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>N = 22</td>
<td>N = 18</td>
<td>N = 17</td>
</tr>
</tbody>
</table>

<sup>+</sup> Sig. at .01 level on a two-tailed Wilcoxon Test.

**TABLE 16**

*Comparison of Motor Scores in Conditions 2 and 3 of Experiment 5*

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 33 (NS)</td>
<td>T = 4&lt;sup&gt;+&lt;/sup&gt;</td>
<td>T = 10 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 12</td>
<td>N = 10</td>
<td>N = 9</td>
</tr>
<tr>
<td>Female</td>
<td>T = 28 (NS)</td>
<td>T = 23 (NS)</td>
<td>T = 4&lt;sup&gt;++&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>N = 11</td>
<td>N = 11</td>
<td>N = 9</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 114 (NS)</td>
<td>T = 53.5&lt;sup&gt;++&lt;/sup&gt;</td>
<td>T = 29.5&lt;sup&gt;++&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>N = 23</td>
<td>N = 21</td>
<td>N = 18</td>
</tr>
</tbody>
</table>

<sup>++</sup> Sig. at .01 level on a two-tailed Wilcoxon Test.
Comparison of intrusive motor and verbal responses within each of the incompatible conditions.

**TABLE 17**

Comparison of Intrusive Motor and Verbal Responses in Conditions 2 and 3 of Experiment 5

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Condition 2</th>
<th>Condition 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>$T = 8$ (NS)</td>
<td>$T = 0^{**}$</td>
</tr>
<tr>
<td></td>
<td>$N = 8$</td>
<td>$N = 7$</td>
</tr>
<tr>
<td>Female</td>
<td>$T = 8$ (NS)</td>
<td>$T = 7.5$ (NS)</td>
</tr>
<tr>
<td></td>
<td>$N = 8$</td>
<td>$N = 8$</td>
</tr>
<tr>
<td>Combined</td>
<td>$T = 29^+$</td>
<td>$T = 9.5^{**}$</td>
</tr>
<tr>
<td></td>
<td>$N = 16$</td>
<td>$N = 15$</td>
</tr>
</tbody>
</table>

**NS** Sig. at .01 level on a two-tailed Wilcoxon Test.

$^*$ Sig. at .01 level on a two-tailed Wilcoxon Test.

+ **.05** gives

These results will be discussed in conjunction with those of the next experiment.

**EXPERIMENT 6. COMPATIBLE AND INCOMPATIBLE SELF-INSTRUCTIONS IN A SENSORY-MOTOR TASK: II. EFFECT OF INCREASE IN LOAD**

This experiment is essentially the same as Exp. 5 except that (a) it is performed on a different and slightly younger group of children, and (b) the presentation of the stimuli was considerably more rapid than in the above. Exp. 6 thus tests Luria's theory under conditions of increased task load. Because the hypotheses, experimental design, apparatus and procedure
were identical to Exp. 5 only those features which differed will be described below.

**Subjects**

The Ss were drawn from another class of the same school used in Exp. 5. As before the final 12 boys and 12 girls on the register were used, the remainder taking part in pilot experiments. Again no S had to be eliminated through sensory-motor defects or through unwillingness to cooperate. Details are given in Table 18 below.

**TABLE 18**

<table>
<thead>
<tr>
<th>Subject Group</th>
<th>Number</th>
<th>Mean Age in Months</th>
<th>S.D.</th>
<th>Mean Peabody Test Score$^h$</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>12</td>
<td>80.1</td>
<td>2.4</td>
<td>68.6</td>
<td>10.1</td>
</tr>
<tr>
<td>Female</td>
<td>12</td>
<td>79.9</td>
<td>2.3</td>
<td>68.3</td>
<td>7.2</td>
</tr>
</tbody>
</table>

$^h$ Raw Score. See Appendix I.

**Stimuli**

Exactly the same sequence of lights were used as in Exp. 5 but the speed of the tape recorder which drove the lamps was increased. This produced a sequence of signals of 0.5 sec. duration, with an inter-stimulus interval of 1.0 sec. The duration of the preparation period between the tape recorder being switched on and the sequence beginning was 1.0 sec. The test sequence
was manually delivered at the same speed as in Exp. 5.

Scoring Methods and Criteria

These were exactly the same as in Exp. 5 except for one slightly different convention that had to be adopted because of the faster pace of the tasks. This concerned the verbal responses which were still recorded by E. Because of the high speed of responding it was found, in pilot experiments, that E could not be confident that the record of the verbal response had been entered against the right stimulus. This problem was aggravated by the fact that the greater difficulty of the task meant that some Ss were only able to produce isolated responses which were particularly difficult to locate. To solve this problem the following scoring convention was adopted for the verbal responses: verbal responses were scored so as to maximise the number of correct responses and minimise the number of intrusions. Thus in a condition requiring the response 'blue' to a red light an isolated 'blue' would be assumed to be a response to a red rather than blue light. This convention works to the Ss' favour in the C and I scores but leaves the reliability of the missing response score (M) unchanged. When necessary, account will be taken of this fact when discussing the results.

The scoring convention for the motor responses was exactly the same as in Exp. 5.

Results

These will be analysed in the same order as in Exp. 5.
**Fig. 33**

**Mean number of correct motor responses**

**Fig. 34**

**Mean number of missing motor responses**
MEAN NUMBER OF INTRUSIVE (OPPOSITE) MOTOR RESPONSES

FIG. 35

MEAN NUMBER OF CORRECT VERBAL RESPONSES

FIG. 36
MEAN NUMBER OF MISSING VERBAL RESPONSES

FIG. 37

MEAN NUMBER OF INTRUSIVE (OPPOSITE) VERBAL RESPONSES

FIG. 38
To test Hypothesis 1, the combined motor scores in conditions 1 and 4 are compared with the same score in conditions 2 and 3.

**TABLE 19**  
Combined Motor Scores in Conditions 1 and 4 compared with Combined Motor Scores in Conditions 2 and 3 of Experiment 6

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>$T = 16$ (NS)</td>
<td>$T = 5^*$</td>
<td>$T = 37$ (NS)</td>
</tr>
<tr>
<td></td>
<td>$N = 12$</td>
<td>$N = 12$</td>
<td>$N = 12$</td>
</tr>
<tr>
<td>Female</td>
<td>$T = 6^*$</td>
<td>$T = 8.5^+$</td>
<td>$T = 31.5$ (NS)</td>
</tr>
<tr>
<td></td>
<td>$N = 12$</td>
<td>$N = 12$</td>
<td>$N = 12$</td>
</tr>
<tr>
<td>Combined</td>
<td>$T = 37.5^*$</td>
<td>$T = 25.5^*$</td>
<td>$T = 141$ (NS)</td>
</tr>
<tr>
<td></td>
<td>$N = 24$</td>
<td>$N = 24$</td>
<td>$N = 24$</td>
</tr>
</tbody>
</table>

* Sig. at .005 level on a one-tailed Wilcoxon Test.
+ " " .01 " " " " " "

**TABLE 20**  
Comparison of Motor Scores in Conditions 1 and 2 of Experiment 6

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>$T = 1.5^*$</td>
<td>$T = 2.5^*$</td>
<td>$T = 14$ (NS)</td>
</tr>
<tr>
<td></td>
<td>$N = 11$</td>
<td>$N = 12$</td>
<td>$N = 9$</td>
</tr>
<tr>
<td>Female</td>
<td>$T = 2^*$</td>
<td>$T = 10^+$</td>
<td>$T = 13.5$ (NS)</td>
</tr>
<tr>
<td></td>
<td>$N = 12$</td>
<td>$N = 12$</td>
<td>$N = 11$</td>
</tr>
<tr>
<td>Combined</td>
<td>$T = 6.5^*$</td>
<td>$T = 24^*$</td>
<td>$T = 43.5^+$</td>
</tr>
<tr>
<td></td>
<td>$N = 23$</td>
<td>$N = 24$</td>
<td>$N = 20$</td>
</tr>
</tbody>
</table>

* Sig. at .005 level on a one-tailed Wilcoxon Test.
+ " " .01 " " " " " "
TABLE 21
Comparison of Motor Scores in Conditions 1 and 3 of Experiment 6

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 1#</td>
<td>T = 1.5#</td>
<td>T = 12#</td>
</tr>
<tr>
<td></td>
<td>N = 12</td>
<td>N = 12</td>
<td>N = 12</td>
</tr>
<tr>
<td>Female</td>
<td>T = 0#</td>
<td>T = 5#</td>
<td>T = 8.5+</td>
</tr>
<tr>
<td></td>
<td>N = 12</td>
<td>N = 11</td>
<td>N = 12</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 1#</td>
<td>T = 16.5#</td>
<td>T = 38#</td>
</tr>
<tr>
<td></td>
<td>N = 24</td>
<td>N = 23</td>
<td>N = 24</td>
</tr>
</tbody>
</table>

\# Sig. at .005 level on a one-tailed Wilcoxon Test.
\+ " " .01 " " " " " " 
\#\# " " .025 " " " " " 

Data relevant to Hypothesis 2.

TABLE 22
Comparison of Motor and Verbal Scores when Conditions 2 and 3 of Experiment 6 are combining

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 19 (NS)</td>
<td>T = 15.5 (NS)</td>
<td>T = 12 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 10</td>
<td>N = 9</td>
<td>N = 10</td>
</tr>
<tr>
<td>Female</td>
<td>T = 1#</td>
<td>T = 21.5 (NS)</td>
<td>T = 11##</td>
</tr>
<tr>
<td></td>
<td>N = 9</td>
<td>N = 9</td>
<td>N = 11</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 36.5#</td>
<td>T = 72 (NS)</td>
<td>T = 44+</td>
</tr>
<tr>
<td></td>
<td>N = 19</td>
<td>N = 18</td>
<td>N = 21</td>
</tr>
</tbody>
</table>

\# Sig. at .005 level on a one-tailed Wilcoxon Test.
\+ " " .01 " " " " " 
\#\# \# .025 " " " " " 

Comparison of the motor scores in conditions 2, 3 and 4.

**TABLE 23**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 32 (NS)</td>
<td>T = 13 (NS)</td>
<td>T = 16 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 11</td>
<td>N = 10</td>
<td>N = 11</td>
</tr>
<tr>
<td>Female</td>
<td>T = 32 (NS)</td>
<td>T = 13.5 (NS)</td>
<td>T = 10 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 12</td>
<td>N = 10</td>
<td>N = 8</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 126.5 (NS)</td>
<td>T = 50.5*</td>
<td>T = 143.5 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 23</td>
<td>N = 20</td>
<td>N = 19</td>
</tr>
</tbody>
</table>

* Sig. at .05 level on a two-tailed Wilcoxon Test.

**TABLE 24**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 33 (NS)</td>
<td>T = 21 (NS)</td>
<td>T = 30 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 12</td>
<td>N = 11</td>
<td>N = 11</td>
</tr>
<tr>
<td>Female</td>
<td>T = 22 (NS)</td>
<td>T = 8.5*</td>
<td>T = 27 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 12</td>
<td>N = 11</td>
<td>N = 10</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 104 (NS)</td>
<td>T = 52.5+</td>
<td>T = 103 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 24</td>
<td>N = 22</td>
<td>N = 21</td>
</tr>
</tbody>
</table>

+ Sig. at .02 level on a two-tailed Wilcoxon Test.

\* \* .05 \* \* .05 \* \* .05
Motor responses in compatible conditions compared with one another.

### TABLE 25
Comparison of Motor Scores in Conditions 1 and 4 of Experiment 6

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 0️⃣</td>
<td>T = 3️⃣</td>
<td>T = 2.5️⃣</td>
</tr>
<tr>
<td></td>
<td>N = 11</td>
<td>N = 12</td>
<td>N = 12</td>
</tr>
<tr>
<td>Female</td>
<td>T = 1️⃣</td>
<td>T = 7️⃣</td>
<td>T = 11️⃣</td>
</tr>
<tr>
<td></td>
<td>N = 11</td>
<td>N = 11</td>
<td>N = 12</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 2️⃣</td>
<td>T = 22️⃣</td>
<td>T = 28.5️⃣</td>
</tr>
<tr>
<td></td>
<td>N = 22</td>
<td>N = 23</td>
<td>N = 24</td>
</tr>
</tbody>
</table>

* Sig. at .01 level on a two-tailed Wilcoxon Test.

Motor responses in incompatible conditions compared with one another.

### TABLE 26
Comparison of Motor Scores in Conditions 2 and 3 of Experiment 6

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Correct (C)</th>
<th>Missing (M)</th>
<th>Intrusions (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 19 (NS)</td>
<td>T = 27 (NS)</td>
<td>T = 3.5 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 12</td>
<td>N = 11</td>
<td>N = 7</td>
</tr>
<tr>
<td>Female</td>
<td>T = 12️⃣</td>
<td>T = 16 (NS)</td>
<td>T = 1.5 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 12</td>
<td>N = 12</td>
<td>N = 6</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 49️⃣</td>
<td>T = 78.5 (NS)</td>
<td>T = 8️⃣</td>
</tr>
<tr>
<td></td>
<td>N = 24</td>
<td>N = 23</td>
<td>N = 13</td>
</tr>
</tbody>
</table>

* Sig. at .01 level on a two-tailed Wilcoxon Test.
Comparison of the intrusive motor and verbal responses within each of the two incompatible conditions.

**TABLE 27**

Comparison of Intrusive Motor and Verbal Responses in Conditions 2 and 3 of Experiment 6

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Condition 2</th>
<th>Condition 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 15 (NS)</td>
<td>T = 0*</td>
</tr>
<tr>
<td></td>
<td>N = 8</td>
<td>N = 9</td>
</tr>
<tr>
<td>Female</td>
<td>T = 9 (NS)</td>
<td>T = 0*</td>
</tr>
<tr>
<td></td>
<td>N = 8</td>
<td>N = 9</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 44.5 (NS)</td>
<td>T = 0*</td>
</tr>
<tr>
<td></td>
<td>N = 16</td>
<td>N = 18</td>
</tr>
</tbody>
</table>

* Sig. at .01 level on a two-tailed Wilcoxon Test.

**Discussion and Further Analysis**

First, the experimental data will be related to Hypotheses 1 and 2. Second, an alternative to the Luria theory will be developed and also compared with the experimental data. Especially important will be data relating to points where the predictions of the two theories diverge.

**Discussion of Hypothesis 1**

Hypothesis 1 states that motor performance under compatible conditions, that is, accompanied by commands, should be more efficient than under incompatible conditions, that is, accompanied by countermands.
(Let the different speeds of presentation of the stimuli in Exps. 5 and 6 be indicated by calling the Ss of Exp. 5 the low-load group and those of Exp. 6 the high-load group.) For neither the high- nor the low-load group is the hypothesis confirmed for the intrusive responses. The hypothesis is borne out for the high-load group only as far as correct responses are concerned, but by both groups as regards missing responses. So the compatibility of the motor and verbal tasks seems important especially with regard to missing motor responses. Hypothesis 1 is thus supported to some extent, though not very strongly.

**Discussion of Hypothesis 2**

Hypothesis 2 states that where the verbal and motor responses are in opposition, i.e. in incompatible conditions, then there will be more intrusions of opposite responses into the motor than into the verbal outputs. This is not borne out at all for the low-load groups taken as a whole, though it is true for the male Ss taken alone. For the high-load groups on the other hand, it is not true for the male Ss, but it is true for the female Ss taken alone and for the male and female Ss taken as a whole. For the high-load group, then, Hypothesis 2 is fairly strongly supported, though it is only very weakly supported for the low-load group. It must also be borne in mind that the scoring convention biases the results in favour of the hypothesis.
Overall, the two hypotheses derived from Luria's theory gain a certain amount of support from the experimental results, but neither hypothesis is very strongly confirmed. Other theoretical analyses of Exps. 5 and 6 may be equally supported by the data and this would inevitably weaken the significance of even this limited amount of confirmation. The additional information furnished by Exps. 5 and 6 provides grounds for testing Luria's theory against the alternative approach already briefly developed in Chap. 2. This alternative approach stresses information processing capacity limitations, along with more conventional conditioning processes, and dispenses with the idea of the regulatory function of language. It will now be developed in more detail.

The Capacity Theory

Suppose first that the implicit verbal response 'red' has been conditioned to the appearance of red objects such as the red light signals used in the experiments. The production, as a requirement of the experiment, of the response 'blue' to a red signal would require the application of an extra, internal transformation having the form, 'change the response "red" to the response "blue"'. This transformation need not, of course, be enacted consciously; it is perhaps best imagined as embedded in whatever physiological mechanisms subserve linguistic processes. The findings
of Crossman (1956) make it plausible to assume that this extra transformation uses up channel capacity which would not be used up if the overt verbal response was a simple augmentation of the implicit response. (The general argument for this conclusion is that the extra transformation will require an extra step in the computation of the response, and the more elaborated the 'code' connecting stimulus and response the more it will need protecting against random neural 'noise'. Both the computation and the rechecking needed for protection will require channel capacity.) If the task of pressing a red button to a red signal is now conjoined with the requirement to say 'blue' to the signal, then it will not be performed as efficiently as if it were conjoined with the requirement merely to say 'red'. This is because the motor task will have less channel capacity at its disposal, providing, of course, that the S is working near to the limits of his capacity.

The capacity requirements of the different facets of the task can be designated in the following way:

let \( x \) = the capacity requirement of the motor task of pressing a button which is the same colour as the light.

Let \( dx \) = the increment in capacity requirements for pressing the button opposite in colour to the light. The quantities \( y \) and \( dy \) can represent the corresponding capacity requirements for the overt verbal labelling task.

An analysis of the various conditions of Exps. 5
and 6 according to this theory is set out in Table 28, below. The capacity requirements are represented qualitatively in Fig. 39 (a) and the implications for the performance of the motor task are set out in (b).

TABLE 28
Capacity Requirements for the Task
of Experiments 5 and 6

<table>
<thead>
<tr>
<th>Experimental Conditions</th>
<th>Capacity Requirements</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Motor Responses</td>
<td>Verbal Responses</td>
</tr>
<tr>
<td></td>
<td>x</td>
<td>y</td>
</tr>
<tr>
<td>1</td>
<td>x</td>
<td>y</td>
</tr>
<tr>
<td>2</td>
<td>x</td>
<td>y + dy</td>
</tr>
<tr>
<td>3</td>
<td>x + dx</td>
<td>y</td>
</tr>
<tr>
<td>4</td>
<td>x + dx</td>
<td>y + dy</td>
</tr>
</tbody>
</table>

(Comparison with Table 7 may be helpful. N.B. dx, dy need not be small.)

Further Discussion of Hypothesis 1

Luria's theory groups together conditions 2 and 3 in which the motor and verbal responses are at odds with one another. It predicts that they will be more difficult than conditions 1 and 4, which are also grouped together because here the motor and verbal responses are
QUALITATIVE REPRESENTATION OF CAPACITY REQUIREMENTS IN THE FOUR CONDITIONS OF EXPERIMENTS 5 AND 6

Fig. 39 (a)

QUALITATIVE PREDICTION OF PERFORMANCE IN THE FOUR CONDITIONS OF EXPERIMENTS 5 AND 6

Fig. 39 (b)
compatible. The Capacity theory in its simple form also groups together conditions 2 and 3, and like Luria's theory predicts that they will be more difficult than condition 1 (see Fig. 39).

Sufficient data is at hand to reveal that both theories, as they stand, are inadequate on the points above on which they agree. This is because conditions 2 and 3 are significantly different from one another in both the number of correct responses and the number of intrusions. What sort of modifications are required of the two theories? Luria's theory will have to introduce assumptions which stress other factors apart from the incompatibility of the verbal and motor systems. Such assumptions would have to introduce an asymmetry in the Luria analysis of conditions 2 and 3. For the Capacity theory a similar asymmetry is required and could be achieved by discarding the simplifying assumption that the extra capacity requirements caused by S-R incompatibility is the same for the verbal and motor systems, viz. that \( dx = dy \).

In another respect, though, the Capacity theory represents an advance because it highlights a source of weakness in Luria's predictions. Both the Capacity theory and Luria's theory correctly predict that condition 1 should be more easily performed than either of the more complicated incompatible conditions, 2 and 3. But the Luria theory goes further and permits the grouping together of conditions 1 and 4, as in
Hypothesis 1. The limited success of this hypothesis almost certainly arises because condition 4 does not behave in the manner predicted by Luria, e.g. see Fig. 27. What is required is a theory which provides reasons for separating condition 1 from condition 4.

**Hypothesis concerning Condition 4**

Fig. 39 shows that the Capacity theory predicts that condition 4 should be the most taxing one to perform. This distinguishes the predictions of the two theories, because for Luria condition 4 should not be the most taxing. For Luria the main determinant of performance should be the compatibility of the motor and verbal responses. S-R compatibility should only be of minor importance, so conditions 1 and 4 should produce comparable results, because in both the verbal and motor responses are compatible with one another.

These further predictions can now be compared with the experimental data. First the qualitative theoretical graphs (Fig. 39) can be compared with the graphs showing the mean number of correct responses, i.e. Figs. 27 and 33. This suggests that only the low-load group corresponds to the predictions of the Capacity theory. (The high-load group does not accord well with either theory on this test.)

A more accurate picture emerges from the statistical data relating the crucial condition 4 to the other conditions. Taking the low-load group first: in every
case but one, where there is a significant difference between condition 4 and conditions 2 and 3, this is in the direction predicted by the Capacity theory. That is, the correct motor responses in condition 4 are fewer, and missing and intrusive responses greater in number, than in conditions 2 and 3. (The one exception is that the number of missed motor responses by female Ss is significantly greater in condition 2 than in condition 4.) In general, though, the correspondence between the theoretical motor performance graph given by the Capacity theory and the graph of observed correct motor scores for the low-load group is borne out.

Moving now to the high-load group the trend seems to be reversed. Where there is a significant difference between conditions 4 and 2 or 3 - and it only occurs for the missing responses - it is in the direction predicted by Luria. Thus condition 4 produces fewer missing responses than conditions 2 or 3.

The question at issue between the two theories can be pressed further by looking directly at the relationship between conditions 1 and 4. For Luria these are both compatible conditions and should therefore produce very similar results, whereas for the Capacity theory condition 4 should be much more taxing. For the low-load group all performance measures and all groupings of Ss (with one exception) conform to the predictions of the Capacity theory. Condition 4 is significantly more taxing than condition 1. For the high-load group
exactly the same pattern of success for the Capacity theory is revealed, only this time without a single exception. The one exception to the complete success of the Capacity theory is that the female Ss in the low-load group did not miss out significantly more motor responses in condition 4 than condition 1.

Despite the successes of the Capacity theory, the properties of condition 4 do not permit any clear choice between this theory and Luria's. The experimentally established facts are more complicated than allowed for by either theory. The relationship between the two incompatible conditions (2 and 3) and the compatible condition 4 is not adequately accounted for by the simple capacity schema of Table 28, as the data from the high-load group concerning missing responses make clear. On the other hand, the relationship between conditions 1 and 4 is much more clearly explained by the Capacity theory than by Luria's.

Two more situations will now be examined in which differing predictions can be drawn from the two theories.

**Hypothesis concerning Condition 2**

What predictions about the interaction of the verbal and motor systems can be drawn from the Capacity theory?

The most extreme result of competition for channel capacity would be cessation of responses in one modality. Much more likely are (a) intermittent
stoppages, (b) reversion to stereotyped responses, such as alternation or repetition, or (c) reversion to an easier type of response, say a lapse from responses which were incompatible with the stimulus situation to ones which were compatible with it. This last case seems a highly probable strategy for reducing load. Particularly important in the context of Exps. 5 and 6 is that it would produce the appearance of one response system dominating another. Strategy (a) and (b) would afflict the verbal and motor systems equally, but strategy (c) would afflict whichever modality is incompatible with the stimuli. The Capacity theory thus has an explanation for certain cases of the apparent dominance of one response system over another, namely that it is an artefact, and that what is really happening is that a response is reverting under pressure to one compatible with the stimuli.

This analysis leads to the same prediction as Luria’s in condition 3. In this condition it is the motor responses which are not compatible with the stimuli, though the verbal ones are. Any reversion would present the appearance of verbal domination. In condition 2, however, the reverse situation obtains. Here the Capacity theory would predict the apparent domination of the motor system over the verbal system, deviating strikingly from Luria’s theory.

These predictions will now be tested. For the combined male and female Ss in the low-load group there
is a significant difference between the number of verbal and motor intrusions in condition 2. The direction of the difference is that predicted by the Capacity theory and opposite to that predicted by Luria. For the high-load group there is no significant difference in the number of verbal and motor intrusions in condition 2. (But for the high-load group the marking convention for the verbal responses may have minimised the number of verbal intrusions and will be working against the interests of the Capacity theory.) The outcome, then, is that where there is a significant difference between the scores the Capacity theory is well supported. That is, there are more opposite verbal responses than opposite motor responses in a situation in which the motor responses are compatible with the stimuli but the verbal responses are not. This suggests that the Capacity theory is right in placing emphasis on S-R relationships. The difficulty that Ss encounter in condition 2 may be associated with deviating from the response which is 'naturally' associated with the stimuli, rather than because the responses run counter to the verbal set.

The evidence that S-R compatibility is an important variable is well illustrated by the graphs showing the mean number of motor and verbal intrusions for the low-load group. These reproduced below as Fig. 40. Here the lower number of intrusions is associated with whichever response modality is compatible with the
THE INFLUENCE OF STIMULUS-RESPONSE COMPATIBILITY ON MOTOR AND VERBAL INTRUSIONS (DATA FROM EXP. 5)

**Fig. 40**
stimulus. The differences shown in Fig. 40 are significant when male and female Ss are combined. The outcome of this test, then, favours the Capacity theory.

Further Discussion of Hypothesis 2

Luria's theory predicts that the total number of motor intrusions in conditions 2 and 3, where the motor and verbal systems are at odds, should be greater than the total number of verbal intrusions. The Capacity theory predicts that in condition 2 the number of verbal intrusions should be high and the number of motor intrusions low. For condition 3 it predicts the opposite. The total number of verbal and motor intrusions should therefore be approximately the same if the respective motor and verbal scores from these two conditions are combined. (This is assuming that the verbal and motor systems react in the same way to incompatibility with the stimulus, viz. \( dx = dy \).) This prediction of the null hypothesis is better supported than Luria's prediction if attention is restricted to the low-load group; but it fails for the high-load group.

Summary

What emerges from this complicated pattern of results? The only simple thing that can be said is that neither theory, at the moment, can cope with all the data, though they both have their successes. The lengthy discussion has mapped out the area covered by
the two theories, exhibiting the points at which they break down, and the ways in which they complement one another. A detailed grasp of the limitations of the two theories is valuable because it provides the specifications which will have to be satisfied by any new theory in the field. The discussion shows the value that will attach to any successful synthesis of the Luria and Capacity theories. A simple form of such a synthesis will be sketched in the next chapter.
CHAPTER IV

FURTHER DEVELOPMENT OF THE CAPACITY THEORY

The discussion of Exps. 5 and 6 has made it clear that neither Luria's theory nor the Capacity theory, in their present form, can account for all the experimental data. At the very least a synthesis is required. A simple form of such a synthesis will now be sketched and explored. The attempt will be made to modify and expand the Capacity theory in the light of Luria's theory but without, if possible, explicitly adopting the hypothesis that language regulates behaviour.

Both Luria's theory and the Capacity theory can be considered as 'one-factor' theories in that they both stress one single facet of the experimental situations that they have been used to analyse. The factor stressed by Luria's theory is the compatibility of the motor and verbal responses, i.e. R-R compatibility. The factor stressed by the Capacity theory is S-R compatibility, along with its implications in terms of capacity requirements. A synthesis of the Luria and Capacity theories would be a two-factor theory making allowance for both S-R and R-R compatibility.

Outlines of a Two-Factor Capacity Theory

The one-factor Capacity theory can be extended to take account of some of the processes stressed by Luria by the following modification: R-R incompatibility can
be viewed as simply another way in which a task is made more difficult, hence requiring more channel capacity for its proper execution. On this expanded basis another table of capacity requirements for the conditions of Exps. 5 and 6 can be constructed. The procedure will be exactly the same as in the case of the one-factor theory except that the experimental conditions 2 and 3 will have an extra capacity requirement, $dz$, added to allow for the difficulty of R-R incompatibility. This extra difficulty will be absent from conditions 1 and 4. Let $x$ = the capacity requirement of the motor task in its compatible form, and $y$ = the corresponding quantity for the verbal task. Let $dx$ and $dy$ be the increments in capacity requirements produced by S-R incompatibility. $dz$ has already been defined. Then, with the experimental conditions numbered as in Table 7, we have:

**TABLE 29**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Motor Task</th>
<th>Verbal Task</th>
<th>R-R Compatibility</th>
<th>Total Capacity Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Requirement</td>
<td>$x$</td>
<td>$y$</td>
<td>0</td>
<td>$x + y$</td>
</tr>
<tr>
<td>2 Requirement</td>
<td>$x$</td>
<td>$y + dy$</td>
<td>$dz$</td>
<td>$x + y + dy + dz$</td>
</tr>
<tr>
<td>3 Requirement</td>
<td>$x + dx$</td>
<td>$y$</td>
<td>$dz$</td>
<td>$x + y + dx + dz$</td>
</tr>
<tr>
<td>4 Requirement</td>
<td>$x + dx$</td>
<td>$y + dy$</td>
<td>0</td>
<td>$x + y + dx + dy$</td>
</tr>
</tbody>
</table>

Note: $dx$, $dy$ and $dz$ are not necessarily small quantities.
It is now necessary to impose some further constraints on the size and relationships of the quantities $dx$, $dy$ and $dz$, in the above table, so that some qualitative predictions can be drawn from the theory. To begin with, the experimental results so far established strongly suggest that $dx \neq dy$, that is to say, the added difficulty of producing responses incompatible with the stimulus is not the same for the verbal and motor systems. Indeed, for the $S$ of Exps. 5 and 6 the number of correct responses suggests that $dx > dy$, i.e. the increment of difficulty is greater when incompatible motor responses are demanded than when incompatible verbal responses are required.

(This, in itself, is some evidence in favour of a Luria picture because he maintains that the verbal system in children is more 'mobile' and flexible than the motor system.)

Having stated the relationship between $dx$ and $dy$ the relative value of $dz$ must be specified. This is, in effect, an answer to the question of how important is the factor of R-R incompatibility. Suppose first that $dz$ is small compared with $dx$ and $dy$, that is, the effect of R-R incompatibility is very small; then, $dx > dy > dz$. This entails a graph of capacity requirements looking like that in Fig. 41 (a) below. On the assumption that $S$s are working near to the limits of their capacity this leads to the performance predictions of Fig. 41 (b). (Clearly the assumption that $dz$ is small would lead in
NOTE: ASSUMPTION, $dx > dy > dz$

CAPACITY REQUIREMENTS AND PERFORMANCE PREDICTIONS OF THE TWO-FACTOR THEORY ON THE ASSUMPTION THAT $dz$ IS SMALL.

FIG. 41
the limit to the one-factor Capacity theory which is a limiting case of the two-factor theory.)

Quite a different situation obtains, though, if it is assumed that dz is not small, but, say, on a par with dx, the larger of the two increments of difficulty caused by S-R incompatibility. On this assumption a different sort of graph results, as Fig. 42 (a) below shows. On this assumption the third condition is the most taxing, and the second and fourth conditions very similar. #

These hypothetical cases are only two out of an indefinitely large number of possibilities that could be imagined. They do, though, have a special significance: the forms of the graphs in (b) in the above figures corresponds very closely to the graphs of the correct motor responses that were obtained for the low and high-load groups respectively in Exps. 5 and 6. These experimentally derived graphs are given below for comparison with the theoretical curves. (The graphs below show the result for female Ss only, but the form of the graphs for the male Ss is very similar.)

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# A numerical example may make this point clear. Let $x + y = 50\%$ of available capacity, let $dx = 20\%$, $dy = 10\%$, and $dz (= dx) = 20\%$. Then condition 1 requires 50\% capacity, condition 2 requires 80\%, condition 3 requires 90\%, but condition 4 only requires 80\%. These figures are computed by substituting the hypothetical numerical values into the table of capacity requirements, Table 29.
NOTE: ASSUMPTIONS, \( dx > dy \), \( dz = dx \) (approx.)

CAPACITY REQUIREMENTS AND PERFORMANCE PREDICTIONS OF THE TWO-FACTOR THEORY ON THE ASSUMPTION THAT \( dz \) IS LARGE
LOW-LOAD GROUP: COMPARE WITH FIG. 4.1 (b)

HIGH-LOAD GROUP: COMPARE WITH FIG. 4.2 (b)

MEAN NUMBER OF CORRECT MOTOR RESPONSES IN EXPERIMENTS 5 AND 6 SHOWING CURVES OF THE GAME FORM AS THOSE PREDICTED BY THE TWO-FACTOR THEORY

FIG. 4.3
The two factor theory, then, already promises to resolve one interesting anomaly in the experimental results, namely the different forms of the curves for the high- and low-load groups in the graphs giving the number of correct motor responses. It is difficult to see how either one-factor theory could do this. All that is now required is to relate plausibly the assumption that $d_z$ is small to the situation of the low-load group, and the assumption that $d_z$ is large to the situation in which the high-load group operate.

To do this it is necessary to expand the account so far given of the psychological meaning of the parameter $d_z$, and show how it might vary in importance in different experimental conditions. First consider the low-load group. Under conditions of low-load it is plausible to assume that the verbal and motor responses are not in serious competition for resources in the nervous system and can therefore be kept apart with little mutual interference. The 'overlap' of the verbal and motor responses will be very small. In Fig. 44 below, let $G$ represent a 'gate' the size of which limits the total nervous resources shared by the verbal and motor responses. In (a) there is no overlap at all. This is a condition satisfactorily represented by a one-factor Capacity theory. In (b) there is an overlap. This forced sharing of resources with its consequent possibilities for interference will provide the conditions under which the factor $d_z$ becomes
THE ALLOCATION OF RESOURCES BETWEEN THE MOTOR AND VERBAL RESPONSES IN HIGH AND LOW LOAD CONDITIONS

FIG. 14
important. When the rate at which decisions have to be taken is increased the amount of overlap will increase, and the relation between the response modalities may become crucial. If the two response outputs have a similar structure it is plausible to imagine them running in parallel with little or no interference. They may even share facilities in the nervous system, as people going the same route can share a taxi. However, responses having different structures, requiring different computations and transformations will not be able to co-exist in the area of overlap; indeed their presence will ensure that the area of overlap will be one of confusion resulting in missed or erroneous responses. Consequently the size of the effect produced by the dz factor will vary with the size of the area of overlap, that is, with the degree of difficulty of the task. This analysis, then, justifies associating the condition in which dz is given a small value with the low-load group, and the condition in which dz is given a large value with the high-load group.*

So far the only response measure that has been considered is the number of correct motor responses. Attention will now be turned on the remaining two measures. If the graph predicting the number of correct responses can be treated as a simple mirror-image

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* Care has been taken not to represent $G$ as the total capacity available for responses. This would require interpreting $dz$, the area of overlap, as a demand in excess of 100% capacity, and this is not implied in the original definition of the term.
of the capacity requirement graph (i.e. the higher the capacity requirement the lower the number of correct responses) then should not the missing and intrusive response scores both simply have the same form as the capacity graph (i.e. the more capacity is required the more missing and intrusive responses there should be)? Unfortunately this assumption would be quite arbitrary because there is no reason a priori why the two sorts of error should have the same pattern across the different experimental conditions. What is ideally required is some theory about the nature of the errors so that predictions can be made about the form of the graphs. However, lacking any such theory resort must be had to the simple and arbitrary assumption that the error curves both follow the capacity curve. This assumption, incidentally, has been made implicitly throughout the previous discussions of Exps. 5 and 6. The consequences of this assumption will now be examined.

**Missing Motor Responses**

For the high load group there are fairly large numbers of missing responses and these do indeed closely follow the same form as the capacity requirements. That is to say that the number of missing responses rises across conditions 1, 2 and 3 at which it is at its peak. The number then declines in condition 4 to approximately the same number as in condition 2. The graphs of both the male and female Ss taken separately
have this form. The simple assumption is thus borne out for the high-load group, but it fails when tested against the low-load group. Here the graph of the number of missing responses does not follow a monotonically rising curve as it should do if it were following the capacity requirement curve for this group. The number of missing responses for the low-load group, though, is on average very low indeed, so it is perhaps not surprising that no trend can be discerned.

**Opposite or Intrusive Motor Responses**

Both the high- and the low-load groups present a picture of steadily increasing numbers of opposite motor responses across conditions 1 to 4. This form of graph is correct for the low-load group but not (on the simple assumptions being made) for the high-load group.

It looks superficially as if the low-load group behave as predicted, but the result has an anomalous feature which deserves closer examination. This is that the mean numbers of opposite responses is higher for the low-load group than for the high-load group. For the high-load group the mean number of opposite responses rises to around 5 (for male Ss), for the low-load group it rises to around 9 (again for male Ss). This is odd because errors of intrusion are presumably caused by the overlapping of the verbal and motor channels, a feature that should be associated with the high- but not the low-load group. Examination of the
raw data explains the anomaly, the cause of which is disguised by looking only at mean values. The low-load group consists mainly of Ss with very low opposite response scores, but a few Ss made a very high number of opposite responses. It is these Ss who are responsible for the high average scores. What seems to be happening is that a number of low-load Ss change the 'rule' according to which they make their responses and proceed systematically to produce the opposite of what is required of them. The error lies in the initial 'set' of the S, in the task that he chooses to do, rather than in any difficulty in executing the assigned task. Why should this happen more often to the low-load group rather than the high-load group? A possible explanation concerns the much longer gaps between stimuli and the longer gap before the beginning of the experimental runs. These gaps provide time for the rehearsal or attempted rehearsal of instructions, and it may be in this process that error creeps in.

This suggestion, though made on an ad hoc basis, is one very small step towards producing a theory of the mechanisms underlying the different sorts of errors, a requirement whose importance was stressed earlier. In this case, though, it must be noted that the mechanism invoked, namely the initial 'set' governing the responses, is a quite different sort of process to one which could be integrated into either Luria's theory or a one or two-factor Capacity theory. These theories ideally
require explanations of errors purely in terms of the ongoing processes of self-instruction or response organisation which are at work during the production of a sequence of responses. An explanation in terms of 'set' is invoking extra and different mechanisms which come into play before the stages dealt with by the Luria or Capacity theories.

The fact that there may be two rather different processes at work producing opposite responses means that the monotonically increasing graph of numbers of opposite responses for the low-load group may be something of an artefact. It should not therefore really count as a success for the simplified hypothesis concerning error prediction that is being examined. The outcome, then, is that the distribution across the experimental conditions of the opposite motor response scores cannot be explained, either for the high- or the low-load groups.

The three out of four failures to explain the error scores need not, though, be considered particularly dangerous for the Capacity theory. The failures in fact occur in an area in which the theory is silent rather than in an area in which it makes specific predictions. The one prediction that did succeed followed from an extremely simple and rather arbitrary extension of the theory and there is plenty of room for adjustment.

Most of the issues dealt with so far concern the relation of the two-factor theory to the data connected
with Hypothesis 1 of Exps. 5 and 6. To conclude the
discussion of the two-factor theory it will be related
to data concerning Hypothesis 2. The two-factor theory
in effect reproduces the predictions of the one-factor
Capacity theory in this area. In other words it
assumes that the motor system will appear to dominate
the verbal system in condition 2 and that the verbal
system will appear to dominate the motor system in
condition 3. The real process will be the lapse into
compatibility of whichever modality is incompatible with
the stimuli. The reason why the two-factor theory is
the same here as the one-factor Capacity theory is
because, although it accepts the interference of the
verbal and motor systems, it contains no postulate
concerning the genuine domination of one response system
over another when there is competition. It was for
this reason that the two-factor theory was introduced as
a synthesis which only took account of some of the
processes stressed by Luria. Because of this limitation
the two-factor theory as it stands will necessarily fail
to explain the apparent fact that the high-load Ss do
show evidence that, when conditions 2 and 3 are combined,
the number of motor intrusions is greater than the
number of verbal intrusions. It appears that the two-
factor theory may need supplementing with a genuine

* It is difficult to know, though, how much weight to
place on this result because here Luria's theory is
aided by the scoring convention that was adopted for
the verbal responses. So it is possible that this
result is an artefact.
Luria component which comes into play to regulate the interaction of the verbal and motor systems and which postulates that the verbal will dominate the motor. If this is so, then the efforts to account for the experimental data without recourse to the regulatory postulate will have failed. The reliability of the experimental techniques used to record the number, nature and timing of the verbal responses is thus of quite crucial importance. This provides a strong reason for repeating certain aspects of the previous experiment, in particular the two incompatible conditions (2 and 3) using different and more objective means of recording the verbal responses. Only then will it be clear if there are unavoidable grounds for retaining the postulate that language is exercising a regulatory function in the conditions being studied.

EXPERIMENT 7. A COMPARISON OF VERBAL AND MOTOR ERRORS IN THE TASK OF EXPERIMENT 6

The purpose of this experiment is to provide an accurate measure of the number of motor and verbal errors in a task where the verbal response to a stimulus is at odds with the motor output, e.g. in pressing one of a pair of response keys but verbalising the label for the other. The previous experiment has left this issue in some doubt due to difficulty in recording the timing of the verbal responses. Accurate data on this issue is necessary because it will determine whether, in the
last analysis, the existence of processes of verbal regulation must be accepted. Because of the limited focus of the present experiment only the two relevant experimental conditions will be extracted from the previous experimental design.

Hypothesis

Where the verbal system and the motor system are in competition (e.g. when pressing the blue button but saying 'red' in the task of Exp. 6) then the verbal system will predominate over the motor system and Ss will tend to press the wrong button more frequently than they will say the wrong word. (The alternative hypotheses derived from the Capacity theory will be introduced in the discussion section.)

Subjects

The 40 Ss were the pupils of the Milton House Primary School, Edinburgh, and the South Bridge Primary School, Edinburgh. Half of the Ss were from each school with equal numbers of boys and girls in each sample. No Ss had sensory-motor defects and none had to be eliminated through failure to cooperate. The Ss were chosen by simply working down the class registers. The details are given in Table 30 below.
TABLE 50

Details of the Subjects of Experiment 7

<table>
<thead>
<tr>
<th>Subject Group</th>
<th>Number</th>
<th>Mean Age in Months</th>
<th>S.D.</th>
<th>Mean Peabody Test Score</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>20</td>
<td>78.8</td>
<td>5.1</td>
<td>60.2</td>
<td>8.8</td>
</tr>
<tr>
<td>Female</td>
<td>20</td>
<td>79.8</td>
<td>2.9</td>
<td>61.3</td>
<td>11.1</td>
</tr>
</tbody>
</table>

* Raw Score. See Appendix I.

Experimental Design

The design is essentially a truncated version of that used in Exp. 6. The Ss were presented with the same sequence of red and blue light signals as in the previous experiment, and in one condition they had to press a button the same colour as the light but say the name of the other colour. In the other condition the verbal response corresponded to the colour of the signal, and it was the motor response which was incompatible with the stimulus. These conditions will be referred to from now on as condition 2 and condition 3 respectively, as in Exp. 6. All Ss were given both conditions, half in one order, half in the other, with equal numbers of boys and girls in each group.

Apparatus

This was essentially the same as in Exp. 6, but with an important modification. In Exp. 6 Ss had their verbal responses recorded by E. In this case the
verbal responses were recorded by a tape recorder. This alone would not have solved the problem of correlating the verbal and motor responses. But as well as this — for reasons to be made clear — the microphone was fastened to the front of the S-R unit. (This meant that the microphone was directly facing the S at a little below chest height as he sat with the S-R unit on a table in front of him. Pilot studies had shown that with the microphone in this position no special instructions had to be given to the S to speak into it, other than the usual requirement not to whisper, a fault which, if it occurred, was eliminated in pretraining.)

The result of attaching the microphone to the front of the S-R unit was that it recorded both the S's verbal responses and also picked up, through the casing, the click of the buttons being pressed. It was then possible to correlate the clicks with the pen recording of the button presses, which, of course, indicated the difference between a red and blue press. In this way the timing and position of the verbal responses could be accurately included in the graphic record of the motor responses and the different sorts of error determined by inspection. On the few occasions when it was difficult to establish the order of the clicks and the words, the tape was played through at a slower speed and the problem resolved. Accurate recording of the verbal responses could now be achieved and the bias of the scoring convention that had to be adopted in Exp. 6 was eliminated.
Procedure

This was exactly the same as in the previous experiment, except that only the two R-R incompatible conditions were used.

Results

The most important result concerns the relative number of verbal and motor intrusions. The data bearing on this will be presented both for the original group of 40 Ss and also for two specially selected subgroups.

1) Comparison of the total number of verbal and motor intrusions when the scores of both experimental conditions are combined. The tables below show the result of applying a Wilcoxon matched-pairs test to see if there is a significant difference between the numbers of verbal and motor intrusions.

TABLE 31
Comparison of Motor and Verbal Intrusions when Conditions 2 and 3 of Experiment 7 are Combined

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Conditions 2 and 3 Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>( T = 82.5 ) (NS) ( N = 19 )</td>
</tr>
<tr>
<td>Female</td>
<td>( T = 58 ) ( (NS) ) ( N = 15 )</td>
</tr>
<tr>
<td>Combined</td>
<td>( T = 286 ) ( (NS) ) ( N = 34 )</td>
</tr>
</tbody>
</table>
2) Comparison of the number of intrusive motor and verbal responses within each of the two experimental conditions treated separately. The mean numbers of intrusive motor and verbal responses are given in Figs. 45 and 46.

**TABLE 32**

Comparison of Motor and Verbal Intrusions within Conditions 2 and 3 of Experiment 7

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Condition 2</th>
<th>Condition 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>T = 52.5 (NS)</td>
<td>T = 31 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 16</td>
<td>N = 14</td>
</tr>
<tr>
<td>Female</td>
<td>T = 41.5 (NS)</td>
<td>T = 8 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 15</td>
<td>N = 9</td>
</tr>
<tr>
<td>Combined</td>
<td>T = 184 (NS)</td>
<td>T = 69*</td>
</tr>
<tr>
<td></td>
<td>N = 31</td>
<td>N = 23</td>
</tr>
</tbody>
</table>

* Sig. at .05 level on a two-tailed Wilcoxon Test.

3) The same comparisons as above will now be made with a selected subgroup of 'high-scorers'. First, though, the selection of the subgroup will be described. The idea was to filter out those Ss who were not maintaining the required motor set and who lapsed into making very few correct motor responses. On this basis only those Ss were retained for consideration who scored more than 5/20 correct motor responses on both of the experimental runs. Some of these Ss were then eliminated in order to leave a subgroup which was balanced in terms of the order of presentation of the experimental conditions. This was done by sorting the Ss into two groups depending
on the order of presentation of the experimental conditions and then selecting from the larger group Ss who matched those in the smaller group in terms of the mean number of correct motor responses. Where there was more than one such S to choose from that one was selected whose performance was least favourable to the Capacity theory’s predictions about the number of motor and verbal intrusions in condition 2. This left a sub-group of high scorers of N = 12. No attempt was made to balance the sex ratio of the group in which there were twice as many female as male Ss.

The mean number of motor and verbal intrusions in the two experimental conditions for the high scores are given in Fig. 47.

### TABLE 33

Comparison of Motor and Verbal Intrusions for the High Scorers in Experiment 7

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Condition 2</th>
<th>Condition 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selected Subgroup of High Scorers</td>
<td>T = 2.5*</td>
<td>T = 10.5 (NS)</td>
</tr>
<tr>
<td></td>
<td>N = 9</td>
<td>N = 7</td>
</tr>
</tbody>
</table>

Conditions 2 and 3 Combined

- T = 19 (NS)
- N = 11

* Sig. at .02 level on a two-tailed Wilcoxon Test.
4) Another issue which will be considered in the discussion section concerns the tendencies of Ss to ignore one response channel in favour of the other, e.g. devoting themselves to giving correct motor responses at the expense of correct verbal responses. One plausible measure of such bias is the number of responses which are missed out in the respective response channels. On this measure missing out equal numbers of motor and verbal responses would suggest equal allocation of capacity. (The limitations of this assumption will be mentioned later.) Figs. 48 and 49 show the number of missed motor and verbal responses for each S in conditions 2 and 3. Let those Ss who miss out equal numbers of motor and verbal responses in any one of the conditions be called the 'unbiased group' for that condition (these groups will not necessarily be the same for the two conditions). Inspection of the graphs shows that by a fortunate chance both the unbiased group for condition 2 (N = 32) and the unbiased group for condition 3 (N = 26) are balanced for the order of presentation of experimental conditions. Table 34 compares the number of verbal and motor intrusions in the two experimental conditions for the appropriate unbiased groups. Fig. 50 shows the mean number of such intrusions in the two conditions. The point of selecting unbiased groups will be explained in the discussion section.
TABLE 34
Comparison of Motor and Verbal Intrusions in Conditions 2 and 3 for the Unbiased Groups in Experiment 7

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Comparison of number of motor and verbal intrusions (Wilcoxon Test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unbiased Group for Condition 2</td>
<td>T = 80.5, N = 24, sig. at .05 level on a 2-tailed test</td>
</tr>
<tr>
<td>N = 32</td>
<td></td>
</tr>
<tr>
<td>Unbiased Group for Condition 3</td>
<td>T = 26, N = 15, (z = 1.93, p &lt; .054 on a 2-tailed test)</td>
</tr>
<tr>
<td>N = 26</td>
<td></td>
</tr>
</tbody>
</table>

The more general features of the performance of the Ss of Exp. 7 will now be examined in order to compare them with the trends that were seen in Exp. 6, and so that they may be related to the Capacity theory in the discussion section. The following data all applies to the original group of Ss, not to the selected subgroups.

5) Comparison of numbers of correct, missing and intrusive responses in conditions 2 and 3. In the table below the scores of the male and female Ss have been combined. The graphs showing the mean numbers of the various motor and verbal scores are given in Figs. 51 to 56.
### TABLE 35

**Comparison of Motor and Verbal Responses**

**in Conditions 2 and 3 of Experiment 7**

when Male and Female Subjects are Combined

<table>
<thead>
<tr>
<th>Response Modality</th>
<th>Correct $T$</th>
<th>Missing $T$</th>
<th>Intrusive $T$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motor</strong></td>
<td>224.5*</td>
<td>167.5**</td>
<td>293.5 (NS)</td>
</tr>
<tr>
<td>Responses</td>
<td>N = 38</td>
<td>N = 36</td>
<td>N = 37</td>
</tr>
<tr>
<td><strong>Verbal</strong></td>
<td>131+</td>
<td>225.5 (NS)</td>
<td>195.5 (NS)</td>
</tr>
<tr>
<td>Responses</td>
<td>N = 39</td>
<td>N = 36</td>
<td>N = 35</td>
</tr>
</tbody>
</table>

**Sig. at 0.01 level on a two-tailed Wilcoxon Test.**

* * * .05 ** ** ** **

+ * * .005 ** ** **
MEAN NUMBER OF MOTOR AND VERBAL INTRUSIONS FOR MALE SUBJECTS

**FIG. 45**

MEAN NUMBER OF MOTOR AND VERBAL INTRUSIONS FOR FEMALE SUBJECTS

**FIG. 46**
MEAN NUMBER OF MOTOR AND VERBAL INTRUSIONS FOR THE HIGH SCORING SUBJECTS

FIG. 4.7


MEAN NUMBER OF MOTOR AND VERBAL INTRUSIONS FOR THE UNBIASED GROUPS

FIG. 50

(Figs. 48 and 49 over page)
RELATION BETWEEN THE NUMBER OF MISSED MOTOR AND VERBAL RESPONSES IN CONDITION 2

FIG. 48
UNBIASED RESPONSES  O BIASED RESPONSES

**Fig. 49**
Mean number of correct motor responses

Fig. 51

Mean number of missing motor responses

Fig. 52
NUMBER OF INTRUSIVE RESPONSES

MEAN NUMBER OF MOTOR INTRUSIONS

FIG. 53

NUMBER OF CORRECT RESPONSES

MEAN NUMBER OF CORRECT VERBAL RESPONSES

FIG. 54
MEAN NUMBER OF MISSING VERBAL RESPONSES

FIG. 55

MEAN NUMBER OF VERBAL INTRUSIONS

FIG. 56
Discussion

The main purpose of Exp. 7 was to test the hypothesis that in the conditions of the experiment there would be more mistakes of pressing the wrong button than of saying the wrong word. This hypothesis is in accordance with Luria's theory that the verbal system dominates the motor system in a situation in which they are at odds with one another, as they were in the conditions of this experiment.

The results show that when the combined scores of the two experimental conditions are considered together there is no evidence that there are more motor than verbal intrusions. Luria's hypothesis, then, is not borne out by this experiment.

Inspection of Figs. 46 and 47 suggests why Luria's hypothesis is not supported by the data. In condition 3 (where the motor responses are incompatible with the stimuli) there is indeed a higher number of motor than verbal intrusions. In condition 2, however, the situation is reversed: there are a higher number of verbal than motor intrusions. In this respect, then, the graphs are identical in form to those of Exp. 5 where the same relative positions of the mean numbers of verbal and motor intrusions were found (see Fig. 40). It is this reversal of the relative numbers of verbal and motor intrusions in the two experimental conditions that evidently stops the overall means for the two sorts of errors from being different. The graphs are not of
the form that would be predicted by the verbal regulation theory, which would expect that the number of motor intrusions would be greater than the number of verbal intrusions in both cases. They are, though, of the form predicted by the Capacity theory. Previous elaboration of the theory has shown how it predicts 'pseudo-dominance' of the verbal over the motor system in condition 3, here agreeing with Luria, but 'pseudo-dominance' of the motor over the verbal system in condition 2.

A statistical examination of the number of intrusions shows that for condition 3 – where the Capacity and the Luria predictions coincide – the differences indicated by the graph are indeed significant. Unfortunately for the Capacity theory in condition 2 the number of verbal intrusions, though greater than the number of motor intrusions, is not significantly different. One reason why the predictions of the Capacity theory in the very important condition 2 have not achieved significance may be because of the presence of Ss who made only a very few correct responses. The Capacity theory predicts the apparent dominance of the motor over the verbal system in a situation of high-load where, under pressure, it proves impossible for the S to sustain the 'set' to reverse his verbal responses, so they lapse into compatibility with the stimulus. Where a S is only making a very few motor responses the preconditions for this apparent
dominance will not hold. In order, then, to give the Capacity theory a real opportunity to show the presence of the totally non-Luria-like phenomenon of apparent motor dominance it is necessary to select a group of high scorers and examine their behaviour in the crucial condition 2. When this is done the fact clearly emerges that there are indeed significantly more verbal than motor intrusions. It would have been very satisfactory if, for this selected subgroup of high scorers, the corresponding lapse of the motor system into compatibility in condition 3 could have been demonstrated. Unfortunately in condition 3 the difference between the number of motor and verbal intrusions does not achieve significance as it does for the larger unselected group. The trend is, though, in the predicted direction.

The procedure of selecting a subgroup of high scorers is not entirely satisfactory and is open to the following objection: suppose that Ss differ in their tendency to ignore one or other of the response channels, say, exhibiting a bias in favour of making correct motor responses at the expense of the verbal channel. If this were so then the technique of selecting Ss with high motor scores would simply select Ss with this response bias. Given such a bias then this group would of course show more errors of intrusion in the verbal than the motor channel. If this argument is sound then the dominance of the motor over the verbal channel might not result from the S-R compatibilities of the various
facets of the task, as the Capacity theory maintains, but could be a mere artefact of selecting Ss with a certain sort of response bias.

To overcome this objection it is necessary to consider the data regarding the 'unbiased groups'. These Ss are not neglecting one task in favour of the other, and in particular are not neglecting the verbal task in condition 2. In this group, as with the high scorers, the result again emerges that in condition 2 it is the incompatible verbal responses which show more intrusions, whilst in condition 3 the greater number of intrusions is shown by the incompatible motor responses. Selecting unbiased groups overcomes the objections to selecting high scorers and reinforces the conclusion that S-R compatibility is the important variable determining the number of verbal and motor intrusions.

Now that the main results of Exp. 7 have been related to the hypothesis under test the discussion can be extended to cover the more general trends in the data. These differ in interesting ways from those encountered before and afford an opportunity to fill out the picture that has been drawn of the workings of the Capacity theory. It also points to ways in which it might be tested.

When the Capacity theory was first introduced the two parameters dx and dy (representing increments of
difficulty in the motor and verbal tasks when incompatible responses are required) were assumed for simplicity to be equal. The real relative sizes of these parameters is not in fact specified by the theory. Clearly whole families of predictions could be drawn from the theory depending on the relative sizes assigned to these terms. (The same point applies to the term $ds$ representing the increment of difficulty due to the need to produce two sets of incompatible responses.) The policy adopted regarding the values of $dx$ and $dy$ was to let the theory follow the facts and to conclude from the observed performance of groups of $S$s which of the two values was the larger. In the case of the group of $S$s used in Exp. 6 it seemed that reversing the motor response was more difficult than reversing the verbal response, viz. $dx > dy$, although there is no reason a priori why this should have been the case or why all groups of $S$s should behave in the same manner in this regard.

An examination of the graphs of the number of correct and missing responses for the group of $S$s of Exp. 7 suggests a reversal of this relationship compared with the $S$s of Exp. 6. In Exp. 6 there is an overall tendency for $S$s to find condition 2 easier than condition 3, while in Exp. 7 it is the condition in which the verbal responses have to be reversed that is found more taxing, i.e. $dx < dy$. Both of these forms of behaviour are perfectly compatible with the Capacity theory but
they do involve the conclusion that there is a difference in balance between the motor and verbal systems in the two groups — and this fact needs explaining.

The degree of difficulty in making a reversal in the verbal labels of a pair of lights might be associated with the general level of verbal fluency and maturity. Imagine two groups of children, one of high verbal fluency, one of low fluency, then they might well be evenly matched on the motor aspect of the tasks of Exps. 6 and 7 but differ with regard to the verbal facets of the task. This equality with regard to motor skills but difference in verbal fluency could easily produce a situation in which the overall levels of performance on condition 3 were approximately equal but the less fluent Ss would find condition 2 markedly more difficult than the fluent group and also (unlike the fluent group) more difficult than condition 3.*

* To make this claim more concrete it will be worked through with hypothetical numerical values to prove that the Capacity theory really does entail these conclusions. Giving the symbols their usual meaning the high fluency group might have the following capacity requirements for the different facts of the task of Exp. 7: \( x + y = 40\%, \ dx = 15\%, \ dy = 5\%, \ dz = 15\% \); and for the low fluency group, \( x + y = 40\%, \ dx = 15\%, \ dy = 30\%, \ dz = 25\% \). Notice that the relationship between \( dx \) and \( dy \) is reversed in the two cases and \( dz \) is larger for the less fluent group. This represents the condition that the interference between the verbal and motor responses becomes greater the less practised the verbal labelling skills. (This is in accordance with the known facts about the facilitating effects of verbal labels depending on their being overlearned, since otherwise they can actively interfere with building up and maintaining a discrimination (Spiker, 1963). Substituting these values into the Capacity theory, see Table 29, the fluent...
Turning from hypothetical cases to the actual Ss of Exps. 6 and 7 it is found that they perform approximately the same in condition 3 and that it is in condition 2 that they differ markedly. What is more, they differ in the way predicted for the hypothetical high and low fluency groups. But is there any reason for assuming that one group consists of verbally fluent children and the other of verbally less fluent ones? The answer is positive: the groups may indeed differ in their speech habits in the way required to account for their different performances. The Ss were drawn from different schools whose catchment areas had markedly different social characters, but more important is the fact that the tables giving the Peabody Vocabulary Test scores for the Ss shows a difference in the mean raw scores of the two groups of some 7 or 8 points (or approximately 12%). The high vocabulary scorers were the Ss of Exp. 6, the low vocabulary group the Ss of Exp. 7 as required by the above account.

This explanation as it stands is clearly ad hoc but it may have some value in that it points to a way in which the Capacity theory might be tested. If the verbal and motor aspects of the task of Exp. 7 were examined in isolation it should be possible to detect Ss

(Footnote contd. from p. 218)

fluent group has a total capacity requirement of only 60% for condition 2 but 70% for condition 3. The less fluent group would have a not too dissimilar requirement of 80% for condition 3, but a full 95% for condition 2.
who have markedly greater difficulty with the motor reversal compared with the verbal reversal, and vice versa. If two such groups can be located the Capacity theory makes predictions about the relative difficulty of the two conditions of Exp. 7 for the different groups when the motor and verbal tasks are combined. In this way, rather than simply waiting for a group of Ss to define themselves, 'after the fact', as it were, as having such and such a relation between \( dx \) and \( dy \), a prior commitment can be made as to the direction of the inequality and its consequences can be tested.

Conclusion

Exp. 6, with its biased recording of the verbal responses, had suggested that perhaps overall there were more motor than verbal intrusions when the two systems were in competition. This would be in accord with Luria's theory of the verbal regulation of behaviour. The more accurate measurements of Exp. 7 permit this suspicion to be dispelled. There is no significant difference, overall, between the number of motor and verbal intrusions when both the incompatible conditions of Exp. 7 are considered together. Rather, the verbal system tends to dominate the motor system when the motor responses are incompatible with the stimuli, and the

\[\text{This test does, though, rest on the assumption that equal numbers of errors in the two response channels represent equal demands for greater capacity and the validity of the test is thus limited by how near or how far this is from the truth.}\]
motor system tends to dominate the verbal system when it is the verbal responses which are incompatible with the stimuli. So no overall postulate of verbal regulation or domination needs to be admitted. Although there are many anomalies the Capacity theory rather than the regulatory hypothesis seems to represent the most revealing way of looking at the data gathered in the last three experiments.
CHAPTER V

SUMMARY AND SUGGESTIONS FOR FURTHER WORK

The purpose of this chapter will be twofold. First of all the theoretical and experimental investigations of the previous chapters will be re-introduced, summarised and surveyed. Second, a number of possible lines of further enquiry will be briefly developed.

Summary and Survey

The central problem has concerned the various claims that have been made regarding the function that language plays in the self-regulation of behaviour. That language is connected with the regulation of behaviour is a truism; people can be instructed how to perform tasks, how to sequence their actions and how to select the goals of their behaviour. The many instances of the regulation of one person's behaviour by another (as in the case of a parent and child or driving instructor and pupil) has led to the idea that a person may act as his own instructor and regulate his own behaviour by means of his own verbal output. On introspective grounds this idea has a certain plausibility. Sets of directions for an unfamiliar route are memorised and repeated at crucial decision points. This is a very 'intellectualistic' model of behaviour in that it suggests that each action is preceded by another more fleeting action of taking thought. The dangers of
infinite regress in this situation are clear and they have led to the condemnation of whole classes of such theories by modern analytical philosophers (for example Ryle (1949) but see Bloor (1970)). Nevertheless, such accounts of behaviour have been taken seriously by many thinkers. One concrete development of such a theory has been by the Soviet psychologist A.R. Luria working within the framework of ideas supplied by his fellow countryman L.S. Vygotsky.

The main thrust of Vygotsky's work as it applied to child development lay, on the one hand, in exhibiting the growth of the classificatory skills which lie at the root of conceptual thinking, and, on the other, in tracing the internalisation of language. It is internalised language, with all the qualitative changes that it has undergone in the process, which mediates the self-regulation of behaviour on Vygotsky's view. Children acquire language skills from the adults around them as an integral part of a process of social interaction and whilst acquiring a host of other behaviour patterns. Regardless of how the process of learning and socialisation is envisaged, the end result is that adults in a large measure succeed in regulating a child's behaviour. There is also little room for doubt that normally the verbal output of the adult plays a significant role. One of Vygotsky's central claims was that the verbal aspect of the parent-figure's role is taken over by the child's own verbal system which becomes
a source of self-instructions. Vygotsky might be looked upon as providing a counterpart to the Freudian theory of the internalisation of the moral sentiments of parent figures in the 'super-ego'.

Luria has sought to experimentally investigate and illustrate the fine structure of the process whose general course was sketched by Vygotsky from the standpoint of social psychology. He sees language as

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**Note:** The complementary character of Vygotsky's and Freud's views may not be an accident. Wortis (1950) says that in the decade after the revolution a number of Soviet psychologists expressed interest in Freud's views. This trend towards 'idealism' was later condemned, as was Vygotsky's book *Thought and Language*. Early work on the influence of words on behaviour was viewed in the 1950s as typical of the heretical attempt to reconcile mechanism and idealism. Interestingly, Luria was on the editorial board of the *International Journal of Psycho-analysis* between the World Wars.

**Note:** Work that is explicitly a development of the social dimension of Vygotsky's thought has been performed by Bernstein (see for example Bernstein, 1965). Bernstein has traced the social class correlates of different styles of linguistic relationship between parent and child. A detailed articulation of goals and the means of achieving them, of snags and errors, of approved and disapproved procedures, is characteristic of the middle class parent and child. A far less linguistically differentiated code of interaction is associated with many working class homes. For example, in this 'restricted code', to use Bernstein's terminology, children are simply told to stop a certain line of behaviour, whereas in the 'elaborated code' they are told to stop it for a specific reason. The elaborated code thus permits children to make finer discriminations about their own behaviour and its impact on other people. The enhanced analytical power which such a child will develop will inevitably be mirrored in more sophisticated possibilities for the choice and regulation of behaviour. Lest it should be thought that Bernstein's work is an ideological tract on behalf of middle class values and habits it should be pointed out that Bernstein's own perspective on the matter is that /
being able to perform its regulatory function in children because, after a certain stage, it is more highly developed than the motor system. It is more 'mobile' and 'flexible' in that it can produce more accurately timed and selected responses. The deficit that Luria - at one stage in his thought - postulated in the motor system is that it suffers from inadequate proprioceptive feedback. The significance of this type of deficit has been well demonstrated in a variety of studies. This claim has been supported by Luria's argument that the introduction of enhanced feedback improves a child's motor skills. For example in a task requiring the pressing of a rubber bulb each time a light flashes a young child's performance is said to be greatly improved if feedback is introduced in the form of a buzzer which sounds when the bulb is pressed. This is the basis of one of Luria's models of the way in which language regulates behaviour; it helps to close a feedback loop and hence takes over the role of the buzzer in the experiment just mentioned.

One of the first theoretical steps was a detailed examination of the way in which Luria's theory depended

(Footnote contd. from p. 224)

that the two codes are determined by, and adapted to, quite different social situations. Under the influence of Durkheim he sees the categories of thought within a culture as determined by the social structure. An extremely interesting set of claims regarding the disadvantages of a highly articulate, individualistic home background is to be found in the recent study by the anthropologist Mary Douglas of the social causes of anti-ritualist attitudes (Douglas, 1970). Douglas's study takes Bernstein's and Durkheim's work as a starting point.
on this model of the feedback loop. The conclusion was that Luria could only make the dependence fully coherent at the expense of being arbitrary. Rather than leaving the issue hanging on purely conceptual arguments an attempt was made to check the experimental results on which Luria's claim rested. If the observed result of introducing enhanced feedback was not as Luria asserted then the 'model' is simply not there to be used at all. Exp. 1 was thus an attempt to replicate Luria's buzzer experiment.²

Two groups of children of approximately 4 and 5 years of age respectively were presented with a sequence of light signals, some yellow, some blue. On the first occasion Ss simply had to press a rubber bulb for the blue but not the yellow signal. On the second run the task was the same but half the children in each group received enhanced feedback in the form of a buzzer which sounded for every press. The hypothesis tested was that the improvement in performance over the two runs would be greater for the feedback groups. The result was that for the older children there was indeed a significantly greater improvement for the feedback groups, but this was not so in general for the younger children.

The implication of this result is that because

² Details of the ages and numbers of Ss used, stimulus values, order of conditions, etc., will not be given in the following brief summaries of the experiments. Only the general outline of the design and the more prominent results will be mentioned.
there was no improvement due to feedback found in the younger group the model situation is not available for use in the way that Luria requires. Indeed, the result goes strongly against Luria because it is precisely the older Ss (who should have less motor deficit) who benefit most from the introduction of feedback. There was in fact a suggestion, though not a statistically significant one, that the younger Ss were impeded by the presence of feedback. An explanation for the results was proposed in terms of an arousal theory.

The second experiment was designed to check another important precondition of the Luria theory, namely that the verbal system in children is more developed than the motor system. The task was similar to that of the previous experiment, involving responding to the blue but not the yellow signals that were presented in a predetermined sequence. There were two conditions, in one the response was a bulb press, in the other it was to utter the word 'go'. Again two groups of children were used, the younger having a mean age of just over 4 years, and the older a mean a few months short of 6.

The result provides at least a small amount of support for Luria. If the Ss of both ages are grouped together then there were significantly less verbal than motor responses missed out. In this respect, then, the verbal system does seem superior to the motor system, although no other measure of performance displayed this
trend. The results clearly showed, however, that the verbal system was only scoring about 2 out of 3 responses correctly. This was completely counter to the impression derived from quoted statements of Luria's which were meant to apply to Ss even younger than those used in this experiment. The second experiment, then, did not exhibit the verbal system working at the level of efficiency that a reader of Luria's might expect; so however the process of regulation is supposed to work, the verbal system did not emerge as being in a position to impose much improvement on the motor system.

The first two experiments related to certain important theoretical details of the process of verbal self-regulation. Although the experiments were very limited in scope they permitted inferences regarding issues which were quite central to Luria's case as he presented it. It is possible, though, to discern a variety of levels in Luria's theoretical ideas and to find a general formulation of his position which is independent of the detailed models which were the focus of the first two experiments. The first chapter ended with this general form of the theory constructed by quoting from Luria's works. The general form of the theory implies that all motor activity in children comes to be verbally mediated after the age of about 5, and that to prevent the participation of the speech system will result in the disruption of motor performance.

The second chapter began with an examination of
some Skinnerian experiments on the regulatory role of verbal 'operants'. This work was explicitly related to the Soviet contributions and focused on the general form of the regulatory thesis. Again the initial stage of the argument was a theoretical analysis of certain key experiments, and again the analysis revealed obscurities surrounding the claims made. In particular the terminology used in the statement of experimental results disguised the fact that sometimes verbal responses interfered with motor responses rather than assisting them or regulating them. This suggested that it may be fruitful to develop an alternative to the regulatory hypothesis stressing the interference between the concurrent performance of a verbal task and a motor task. This step was the first stage in the development of a theory of the relationship of the verbal and motor systems which appealed only to the capacity requirements of the two response modalities. In its first phase, however, the alternative approach was formulated in terms of the older concept of 'load'.

The task of the second chapter was to see if various Skinnerian experiments claiming to demonstrate the regulatory function of language could be accounted for in terms quite different from Luria's. For example, it had been claimed that if children are given a tapping task (with no speed of tapping specified) then making Ss repeat the word 'fast' speeded up their tapping, whilst making them repeat the word 'slow' slowed it down. It
had also been claimed that for 5 to 6 year olds overt verbal responses were more effective than covert or whispered ones, whilst for 6 to 7 year olds it was the covert responses which exerted greater control. The first step to finding an alternative to the regulatory hypothesis was to establish that repeating a word, whether overtly or covertly, imposed a load on the nervous system which would influence the conduct of a motor task. The second step was to see if the allegedly different regulatory influence of the overt and covert responses could be shown to be an artefact due to the different loadings of the two sorts of response. The strategy was to see whether the alleged regulatory influence of the words might be an inverted formulation of what is really a load phenomenon.

In Exp. 3 a group of nursery children and a group of infant school children were given four runs on a tapping task. The first and last runs were simply to establish how fast they could tap. The middle two runs demanded rapid tapping along with the repetition of the word 'fast'. On one occasion the word was repeated aloud, on the other it was whispered. The result was that both the overt and the covert verbal tasks interfered strongly with the rate of tapping. The experiment did not however reveal any significant differences in the loadings imposed by overt and covert responses, although there was a non-significant trend in the direction that would be required to account for the
alleged difference in regulatory function. This experiment, with the repetition of the word 'fast' strongly interfering with the speed of tapping, provides a demonstration, not merely of the failure of self-instructions to have any influence, but of their having the opposite effect.

Objections to this experiment were then considered in order to formulate the line of attack of Exp. 4. For example, it could be argued that a fast tapping task was very demanding so that of course any concurrent verbal task would take its toll. What is required is a knowledge of the different loadings imposed by self-instructions that were compatible with the motor task compared with self-instructions which were not consonant with it. On the regulatory thesis saying 'fast' may impose a load on a fast tapping response, but not as much as saying 'slow'. It was also clear that the influence of such self-instructions on slow tapping should be investigated. Both of these points were taken up in the next experiment which was a comparison of the influence of commands and 'countermands' on a motor task.

A group of infant school children were given four runs on a tapping task. On two of the runs they had to tap rapidly and on two they had to tap slowly. On one fast run and one slow run they had to repeat the word 'fast' and on another fast and slow run they had to repeat the word 'slow'. Half the children repeated the
word aloud (overt group) and half in a whisper (covert group). One of the main results of this experiment was to establish what Exp. 3 had failed to make clear: that for infant school children the overt utterance of the word 'fast' in a fast tapping task imposed a significantly greater load than did the covert utterance of the word. The same trend was discernible for the countermand condition but did not achieve significance. The experiment also established, however, that for the covert group in the rapid tapping conditions Se tapped more rapidly when saying 'fast' than when saying 'slow'. Here the conclusion had to be in favour of the regulatory hypothesis. The meaning of the spoken self-instruction was having a significant effect on the motor performance. What was not proven was the way in which the spoken words were influencing the motor task: it was possible that it was doing so by essentially non-Luria processes, say, by influencing motivation.

At this point some victories had been won by the 'load' picture which stressed the independence of the verbal and motor systems in all respects but competition for capacity. On the other hand a significant piece of evidence in favour of the regulatory hypothesis had also come to light. The predominant relationship between the verbal and motor outputs was given by the 'load' picture, but a significant second order effect was present in which self-instructions seemed to be regulating behaviour.
The next stage in the investigation was to move away from the tapping tasks used in the previous experiments to tasks which would provide more insight into the details of the processes postulated by the regulatory hypothesis. The previous chapter had, however, provided an appropriate setting for the development of some basic theoretical approaches which could be developed into a more thoroughgoing alternative to the regulatory theory. The technique of comparing the effect of commands and countermands was also utilised in the remaining experiments. The experimental task was radically modified so that unlike the simple tapping tasks it involved the repeated analysis of stimuli and the repeated need to make decisions in selecting the required responses. This ensured that the commands and countermands of the verbal output would have ample opportunity to gain a purchase on any verbal processes involved in the organisation of the motor responses.

For the purposes of the next experiments Luria's theory can be put like this: suppose that \( S \) is presented with a sequence of red and blue signals and required to press red and blue buttons, one press per signal. For a \( S \) who is old enough a required motor response of pressing a red button to a blue light and \textit{vice versa} would be mediated by a covert self-instruction. This would perhaps be of the form 'blue, so red', i.e. a combined labelling of the stimulus and a compressed statement of a rule to be followed. Now imagine the \( S \)
also having to produce an overt verbal output which runs counter to the postulated self-instruction: perhaps saying 'blue' when a red press is wanted. Incorrect motor responses would intrude, evoked by the overt verbal response functioning as a self-instruction. But if there is no verbal component involved in the selection of a response then there should be no difference between the amount of interference of commands and countermands. Exps. 5 and 6 were designed to test this picture.

The hypotheses of Exps. 5 and 6 were that (1) motor responses conjoined with compatible overt self-instructions will be performed more accurately than when conjoined with incompatible self-instructions; (2) when the verbal system and the motor system are in competition then Ss will tend to do what they say rather than say what they do, i.e. if they have to say 'red' and press a blue button they will tend to make the mistake of pressing a red button rather than of saying 'blue'.

The basic task has already been outlined, but for the purpose of adequate control four different conditions were required of each S. In two of the conditions the button to be pressed corresponded to the colour of the light but in one case the verbal response was compatible with the button press and in the other case it was incompatible. The remaining two conditions were the same except that the button to be pressed was the 'opposite' to the colour of the light. The Ss were
infant school children. In Exp. 5 the Ss had the stimulus sequence presented quite slowly (low-load group) whilst in Exp. 6 different Ss had it presented more rapidly (high-load group).

The results of the experiments gave a certain amount of support to the hypotheses and hence to the regulatory theory. For example, the compatibility of the motor and verbal responses was a factor significantly affecting the number of motor responses missed out. There was also a significant tendency for the high-load Ss to do what they said rather than say what they did. One qualification to the second result was that the scoring method for the verbal responses was biased in favour of the hypothesis.

A detailed alternative analysis of the experiments was then developed in a form which appealed only to the capacity requirements of the various tasks and conditions, with no mention of verbal regulation. A simple version of the theory was based on the intuitively plausible idea that to respond to a coloured light signal with a button press or a verbal label of the same colour demanded less capacity than responding with a different colour. When applied to the task of Exps. 5 and 6 the simple capacity theory produced radically different predictions to the regulatory theory. Consider the situation where the verbal and the motor responses are compatible with one another, e.g. when the S says 'blue' and presses the blue button. There are two cases, one
in which both responses are compatible with the stimuli and one in which both responses are incompatible with the stimuli. Luria's theory lays exclusive stress on R-R relationships and so predicts that both of these conditions will be equally difficult, say, as measured by the motor responses. The simple form of the Capacity theory, though, lays equally exclusive stress on S-R relationships and so performance should be worse in one case than the other. The results strongly support the Capacity theory.

Other details of the experimental results did not seem to fit either theory. The Capacity theory predicted that the four experimental conditions of Exps. 5 and 6 could be ranked in order of difficulty. The predicted order was largely confirmed for the low-load group, but for the high-load group it was found that what should have been the most difficult condition was on a par with the second easiest. Such anomalies made it clear that the Capacity theory would have to be refined. But any alteration had to preserve the following useful feature of the Capacity theory: it could offer in the case of Exps. 5 and 6 an analysis of what, for Luria, would appear to be the domination of the verbal over the motor system. Consider the case in which the required verbal response but not the motor response was compatible with the colour of the stimulus lights. If the motor responses were to lapse into compatibility with the stimuli as a result of over-
loading then this would present the appearance of verbal domination of the motor system. This theory of 'pseudo-domination' leads to the opposite prediction to Luria's theory in the case where the verbal, but not the motor responses, are incompatible with the stimuli. This results in the pseudo-domination of the motor over the verbal system. For the low-load Ss the predictions of the Capacity theory are confirmed. For high-load Ss, though, there is no significant appearance of motor domination, although known biases in the scoring of the verbal responses were working against the Capacity theory.

The final steps in the study, in Chap. IV, consisted in (i) a further elaboration of the Capacity theory, and (ii) a repeat of certain aspects of the previous experiments in order to improve the recording of the verbal responses and eliminate the scoring bias. A modified form of the Capacity theory was proposed which made allowance for both S-R and R-R compatibility. This 'two-factor' theory both resolved the anomalous ranking of the various conditions of Exps. 5 and 6 in terms of their difficulty and preserved the important predictions about 'pseudo-domination'. The last experiment, Exp. 7, focused on this important prediction of the Capacity theory concerning the possibility of motor domination of the verbal system. This phenomenon is radically at variance with the regulatory picture of language and its occurrence or non-occurrence is thus of the highest importance in judging the merits of the two theories.
The main outcome of the experiment was that, provided the Sa did not bias their responses in favour of either the motor or the verbal channels, then there was indeed evidence of motor domination of the verbal system in the manner predicted by the Capacity theory. The variable which seems to determine the relationship of dominance between the verbal and motor systems is S-R compatibility.

**Proposals for Further Work**

Suggestions regarding the next steps to be taken after a sequence of experiments has been performed are inseparable from the criticisms that can be levelled at the previous work. Some criticisms of the experiments in this study will therefore be stated as a preliminary to spelling out possible directions for further work.

Many of the criticisms of the seven experiments of this study fall into two categories: these concern (i) areas of interest that were completely ignored in the work but which are related to the experiments that were performed, (ii) ways of analysing and approaching the areas that were chosen for investigation, but which were left unexplored.

In the first category is the criticism that none of the experiments has concerned itself with developmental trends. At the most, two age groups have been taken and compared. This has permitted certain important inferences to be drawn regarding developmental claims made by other workers, but it has not been sufficient to
build up an alternative developmental picture. Also in this category is the criticism that none of the skills and tasks used in the experiments has been examined to see how performance varies with practice.

Perhaps of more importance are criticisms of the second category. For example, none of the experiments has allowed a proper picture to emerge of the individual differences between Ss. Different Ss have shown widely different levels of performance and this fact has received inadequate recognition because of the way that the hypotheses have been formulated and tested.

Another major criticism of Exps. 5 and 6 which falls into the second category concerns a theoretical shortcoming. No adequate distinction has been drawn between the capacity requirements of a task and the capacity allocated to it. Clearly, in general, capacity allocations do not necessarily reflect capacity requirements. This study has not dealt with the way in which Ss might have chosen to allocate capacity differentially to one task rather than another. Explicitly instructions were not given to pay equal attention to both tasks, though this was implicit in the training which laid equal stress on both. As Brown (1964) has brought out, in his review of the problems of capacity measurement in a two-task situation, a primary task may be protected by neglect of a secondary task. What is required by the S is a clear understanding of which tasks are important and what sort of errors are
permitted. Lack of instructions on these points does not necessarily mean that the tasks will be subjectively assessed as being of equal importance. For example, in Broadbent's (1956) experiment on a question and answer task a subsidiary buzzer stimulus was consistently perceived as being more important than the primary stimuli, although no instructions had been given on this point. To some extent, then, Exps. 5 and 6 are in danger of breaking the rules laid down in the discussion of the Skinnerian work to the effect that experimental conditions must not be underdetermined.

Some of the difficulty in discerning completely clear patterns in the results may stem from individual differences in the importance attached to the verbal and motor tasks. On the other hand the theoretical difficulty may not in practice have proved as troublesome as it might have done. Inspection of the graphs of Exps. 5, 6 and 7 suggests that, as with some other dual-task experiments, e.g. Olson (1963), there is a tendency for scores on both channels to be positively correlated. (This applies to missing and correct responses.)

A related general difficulty with the sort of task used in Exps. 5 and 6 is that of the comparability of the scores on the verbal and motor tasks. The scores cannot be easily combined: 7 correct motor responses and 5 correct verbal responses do not necessarily reflect the same situation as 7 correct verbal responses and 5 correct motor responses. The exception is the
case where the capacity requirements for a correct response is the same in both modalities. In the present experiment this cannot be guaranteed, although relevant variables like discriminability of stimuli and probability of occurrence of stimuli and response have been equated in the two channels. In the last analysis some assumptions have to be made about the correspondence between empirical measures of performance and postulated processes connecting stimuli and responses, and at one point in a projected test of the Capacity theory the assumption of a simple equivalence in the capacity requirements of responses in the two channels was indeed made. The assumption was also implicit in the appeal to the 'unbiased' groups of Ss where it was argued that an equal number of missed verbal and motor responses indicated an equal allocation of capacity.

In principle it is possible to test the capacity loadings imposed by the tasks of Exps. 5 and 6 on the motor and verbal channels taken separately. This could be done by pairing the separate verbal and motor tasks with the same subsidiary task and instructing Ss to perform the primary task as well as possible and to do the secondary task when they can. The amount of interference on the common subsidiary task would indicate the relative capacity requirements of the two channels. In this way an estimate could be made of the extent of the divergence from equality of demand by the respective channels. This technique has the advantage that it
would be still be applicable even if the performance of the motor and verbal aspects of the task were so easy when taken in isolation that Ss showed perfect performance (for a similar case, see Brown, 1962). The limitations of this approach are, unfortunately, severe. Knowledge of the capacity requirements of isolated tasks does not permit confident predictions about how the tasks will interact if they are conjoined. So the basic theoretical problem cannot be solved directly by experiments of this sort. The most that can be hoped for is that as data increases plausible theories of capacity allocation may emerge to solve the problem indirectly.

Other criticisms can be produced which do not fall under the above heads. For example, it is difficult to see any connection between the tasks chosen in the previously described experiments and real-life situations. What, in other words, is the practical importance of the experiments? In reply it is possible to argue that science normally chooses to tackle the simplified problems that it thinks it can solve rather than the more complicated and important ones that non-professionals think that it ought to solve (see, for example, Kuhn, 1962). Regardless, though, of the historical precedent for 'triviality' the criticism carries some force.

What are the lines of further research that are indicated by the two main categories of criticism? First, proper developmental data needs to be gathered
regarding children's performance on the tasks used in this study. This requirement can perhaps be generalised to include the need to check carefully the developmental claims made by Soviet workers in this sphere. This point arises because the first two experiments of this study produced results which diverged from those claimed by Luria and his co-workers, an experience shared by Jarvis in his 1963 failure to replicate one of Luria's results. In short, there is a need to carefully retrace the thread of empirical claims made by Soviet psychologists because a lack of experimental rigour may well underlie the brief and inadequate accounts that so often reach us of their work. Jarvis, for example, suggests that Luria only used one particular order of presentation of a set of experimental conditions that in a well designed experiment would have been presented in all possible orders. (For Jarvis's comments see Slobin (1966) where the complaints of a Soviet psychologist about experimental standards are also quoted.) Along with the need to study practice effects, then, the two related exercises outlined above provide an extensive area in which work requires to be done.

The developmental work that has been urged would, ultimately, lead to a concern with adult performances. One promising area of application of the experimental techniques used here, and one major snag, will be mentioned. The snag is that the experimental tasks used in the present study will often be too simple for
a young, healthy adult. They need to be made more complicated but without losing their point. The experimental tasks could, also, be used to study the process of ageing, possibly without in any way modifying them. Whatever may be the merits of the Vygotsky–Luria thesis of the regulatory function of language as applied to children it may yield interesting results when applied to the aged. No doubt various strategies exist for coping with the problems of ageing but their general form will involve using one part of the nervous system to take over or assist in a function normally contributed by another part. Verbal mediation could possibly play a more significant role at this stage than earlier.

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Pilot studies have suggested that one way in which the task of Exps. 5, 6 and 7 could be adapted for adult use would be (i) to remove any prior practice of the task, and (ii) equip Ss with earphones through which is presented distracting material, such as a random repetition of the words 'red' and 'blue'. Comparison with non-relevant distracting material might be interesting here. Even with distractions, though, some Ss overcome their initial disorientation after one or two trials and achieve perfect performance, though increased task speed may cure this.

One of Luria's most striking claims for verbal regulations concerns a case which is presented as an example of cortical processes taking over a role usually played by subcortical ones. This concerns cases of Parkinson's disease where the 'injured subcortical apparatus excites repeated tonic responses', preventing the execution of even simple tapping tasks. Such patients can, however, tap appropriately in answer to the question, 'how many wheels has a car?'. This is held to be an example of the patient 'switching his movements into his speech system and subordinating them...to the cortical connections' (Luria, 1959). Broadbent and Heron (1962) have established that older Ss are particularly prone to distraction in tasks involving immediate memory. This suggests that the task of Exp. 5, with stimuli presented /
Using the experimental technique with adults, especially the aged, represents, then, another area into which the work might be extended.

Moving now to the question of individual differences a number of issues require examination. First, is performance on the tasks of this study associated in any enduring way with other characteristics? Do they represent but one facet of a relatively stable personal style? For example, how do impulsive children compare with relatively slow and thoughtful ones? That different relationships obtain between the verbal and motor systems in the two cases is suggested by the fact that some success has been experienced in limiting extreme impulsiveness by teaching a child to verbalise before acting (Falkes et al., 1968). That such techniques work does not establish that they mirror or reveal the processes which inhibit impulsiveness in a normal person: but it is rational to investigate the possibility.

Of considerably greater importance is the following problem: there are two ways in which a child can make mistakes in the tasks of the last three experiments. The first way is to forget or muddle the rule that has to be followed in matching the responses to the stimuli.

(Footnote contd. from P. 244)

presented relatively slowly, in a manner which invites inter-stimulus rehearsal, may well provide a suitable context for studying the distracting power of different auxiliary stimuli, hence revealing the type of verbal mediation involved.
The child may then, of course, succeed in following the wrong rule correctly. The second way of making mistakes is to maintain the correct response set but fail to execute it properly. At one point this distinction was appealed to in analysing results. In general, though, there has not been an adequate theoretical or experimental response to the fact that there are almost certainly two qualitatively different types of Ss mixed up together. Probably the best way of ensuring a homogeneous population of Ss in this regard is to increase the amount of pre-training. To ensure that the result of this is not simply perfect performance Ss could be trained at a slightly slower rate of responding than is required in the experimental runs. An alternative technique is to alter the experimental task used in the last three experiments to a self-paced routine. Ss could then make sure that they were following the required rule before moving on to the next stimulus. Differences in the time taken to complete a set number of responses would then be a measure of task difficulty. A study of the importance of individual differences, and perhaps the introduction of a self-paced variant of the last three experiments represents, then, another area for further work.

The theoretical criticism concerning the distinction between capacity requirements and allocation also suggests lines of further work. One way of manipulating the allocation of capacity between the
verbal and motor tasks would be to introduce a pay-off matrix of relative rewards and costs for different sorts of responses and errors. Some success has been achieved by this method in manipulating the distribution of attention (Kahneman, 1970), and in facilitating the performance of a central task at the expense of a peripheral one (Bahrick, Pitts and Rankin, 1952). This issue relates to another problem previously encountered - that no proper account has been given of the different sorts of error reported in the experiment. These could well reflect overall strategies for performing the task in the same way that capacity distribution represents a strategy. Presumably the number of intrusive responses could be cut down by Ss missing out a response unless they were very sure that it was correct, say, by rehearsing the relevant rule or by rechecking the stimulus or its trace. Likewise cutting down missed responses would perhaps inevitably increase the number of intrusions. This suggests that one line of theoretical development would be to try to analyse the experiments of this study in signal-detection terms, where such trade-off phenomena are well known.

So far the suggestions for further research have mostly dealt with general areas that need investigating. Some specific and concrete suggestions will now be examined regarding particular experiments that would be of theoretical interest. Exps. 5, 6 and 7 presented the S with a visual stimulus and required the production
of a motor response and a verbal response. The key idea was to set the overt verbal response at odds with the postulated inner process of verbal self-regulation. One variant of this would be to make the verbal component part of the stimulus situation rather than a response. If the verbal stimulus were different from that required by the motor system (as postulated by the regulatory hypothesis) then it might interfere with the self-instruction. As in the previous experiment the hypothesis that verbal processes are not involved in the organisation of motor responses would lead to the prediction that the meaning of the verbal label would make no difference to the motor performance. There are practical difficulties concerned with the synchronous production of a sequence of light signals and verbal labels but an experiment along these lines would have a very similar structure to Exps. 5 and 6. As with these experiments it is easy to produce theoretical analyses from the different points of view of the regulatory and capacity hypotheses which yield conflicting predictions. Morton (1969) describes an analogous experiment which shows both the possible fruitfulness of this approach and which also suggests that E could deliver the verbal cues. In Morton's experiment Ss had to sort a pack of cards into six categories depending on how many 'nonsense' shapes were on them. At the same time E spoke the numbers 1 to 6. Ss were told to ignore the distraction, which they soon learned to do, but 'the
interference of the digits could be greatly increased by speaking the digit name always at the instant that the S turned up a card'.

Not only would the above experiment provide another testing ground for the two theories it would also permit the line of research stemming from Luria's work to link with another topic which has long interested psychologists: the Stroop effect. Stroop (1935) established that when the names of colours are written in inks of a different colour (e.g. 'red' written in blue ink) it is difficult to name the colour of the ink because of interference from the meaning of the colour word. The experiment proposed above places the S in a Stroop-like situation. The stimulus field contains a colour and a colour label which is incongruous. The analogy with the Stroop situation could be further strengthened by giving written labels to the response keys rather than surrounding them with coloured patches. Luria would predict that those aspects of the stimulus situation which are bearers of meaning would predominate over those that were not, and this is exactly the prediction that would follow from seeing the experiment as an example of the Stroop test.

So far the similarity of the Stroop effect to Luria's claims is no more than a distant analogy, but the association could be profitably strengthened and exploited by mapping the experiments of the one field onto the other. The proposals for further research
will end with some examples on these lines. Ellison and Lambert (1968) have shown that verbal repetition, which seems to reduce the availability of words, cuts down the interference of the colour names in the Stroop test. If language is indeed a component in the organisation of motor responses then the repetition of words which might seem crucial for a set of responses should impair performance. Another analogous experiment arises as follows: Pritchatt (1968) has generalised the Stroop test by using learned associations between colours and nonsense syllables. The nonsense syllables were then presented printed in different colours from those associated with them. He found that the interference between the syllables and the ink colours depends on the direction of association in the original paired-associate learning situation. Should the interference effect of the incongruous colour name in the projected Luria-Stroop experiment prove a significant one then the experiment could be generalised after the Pritchatt fashion. Instead of coloured light signals and colour names learned associations could be used between, say, illuminated nonsense shapes and nonsense syllables. Perhaps here, too, the direction of the learned association might be a significant variable determining the dominance relationships between the verbal and the motor system.
Conclusion

By way of conclusion the main findings of this study will be listed in seven points.

(1) Enhanced auditory feedback does not greatly improve the performance of 4 and 5 year olds on a typical Luria sensory-motor task. The small improvement observed increased rather than decreased with age, thus conflicting with Luria's claim that in young children the observed motor deficits are due to inadequate proprioceptive feedback.

(2) No evidence was found that in 4 and 5 year olds the verbal system was less 'diffuse' and more organised than the motor system and its overall level of performance was lower than would be expected from Luria's quoted remarks.

(3) Verbal self-instructions were found to have a distinct interfering effect on a simple fast tapping task in 4 and 6 year olds. In the older group this interference varied depending on whether the verbal responses were overt or covert, the overt responses imposing a greater load than the covert. This finding permitted an alternative explanation in terms of load for results that others had attributed to the regulatory function of language.

(4) In 6 year olds there was a significant difference in the load imposed by covert utterance of the word
'fast' as compared with the word 'slow' in a fast tapping task. This may be an example of language having a regulatory function or it may be an artefact due to motivational factors.

(5) In a detailed study of the influence of commands and countermands in a sensory–motor task many important features of the results were accounted for in terms of a theory depending solely on considerations of limited information processing capacity and making no mention of verbal regulation of the motor system.

(6) In particular it has been established that where the motor and verbal systems are in competition there is no general tendency for the verbal system to dominate the motor system. The crucial variable seems to be S–R compatibility. Situations were exhibited where the motor system apparently dominated the verbal system, which is a phenomenon totally at variance with the regulatory theory of language. An explanation for these facts is offered in terms of the Capacity theory.

(7) On the theoretical level an analysis and articulation of Luria's theory of verbal self-regulation is offered as well as the development of an alternative Capacity theory. It is submitted that the Capacity theory is more successful than the regulatory theory in accounting for the experimental findings.

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* The operational meaning of the words 'competition' and 'dominate' is given in the detailed statements of the hypotheses in Exps. 5, 6 and 7.
Throughout the seven experiments of this study the population of Ss has been described in terms of two parameters: (i) age, (ii) the raw score on a modified form of the Peabody Picture Vocabulary Test. The full rules for administering the test are given in the test manual and were followed in all applications of the modified test. (The first 100 items of 'List A' were used.) The Peabody was chosen because it is simple and speedy to administer, although the raw scores have not been related to I.Q. measures for British children. The only difficulty of using it in this country is that a small number of the words are characteristically American. To overcome this, each term which was not likely to be familiar to British children was replaced by another word provided by E. Although these modifications were inevitably rather ad hoc they were small in number and so the test still provided a ready means of characterising the experimental groups and would have quickly identified any S who was radically different from his fellows. The modifications are as follows: the test item number is given, followed by the deleted

\* The Peabody Picture Vocabulary Test is supplied by the American Guidance Service, Inc., Publishers Building, Circle Pines, Minn. 5504.
item and then the substituted target word. This is either a change in the label of the target picture or a word appropriate to another picture on the same page: 20, (baseball) bat, ladder; 25, weiner, cone; 32, caboose, ambulance; 52, thermos, thermos-flask; 70, stunt, trick.
APPENDIX II

DETAILED DEDUCTION OF THE HYPOTHESIS OF EXPERIMENTS 5, 6 AND 7 FROM LURIA'S THEORY

The hypothesis is that countermands will interfere more than commands in the performance of a sensory-motor task. The text of Chap. III only gives a sketch of how the hypothesis is deduced from Luria's theory, so a more elaborate discussion is presented here. A major objection to the conclusion drawn in the text concerns the point of action of the overt verbal utterance on the covert verbal processes which are held to underlie the organisation of the response. Assume that the S is presented, as in Exps. 5, 6 and 7, with a sequence of red and blue signals, and is required to press either a red or blue key, and to say either 'red' or 'blue'.

Now consider the case where the stimulus is a red signal and the required motor response is to press a blue key, and the verbal response is to say 'red'. Let the diagram below represent the two phases of stimulus labelling and response organisation where verbal components are said to be present, and let the numbers 1, 2, 3 and 4 represent the possible stages in the process where the overt utterance of the countermand 'red' might impinge. Clearly if it impinges at (1) it will merely reinforce the labelling of the stimulus and so will not undermine the production of the motor response.
S \rightarrow 'red' \rightarrow 'red so blue' \rightarrow 'blue' \rightarrow \text{motor R}

\text{stimulus labelling} \quad \text{response organisation} \quad \text{instruction to motor system}

(1) \quad (2) \quad (3) \quad (4)

A similar argument applies if the overt countermand impinges at point (2). The effect of directly interfering with the selection of the motor response will only occur if the overt utterance 'red' slips in, as it were, at the point (3) in place of the word 'blue', or at (4) immediately after the completion of the covert self-instruction. On this analysis it looks as if the chances of the covert countermand 'red' helping the production of the blue key press are as great as the chances of it hindering it. The value of this objection lies in the fact that it suggests a framework for understanding the way in which an adult copes with the task of Exps. 5 and 6. The adult would simply remind himself to call out the name of the stimulus, rather than the name of the response, thus he would 'group' the stimuli and responses in a different way than in the other conditions.

Given the apparent range of different points of action of the overt verbal countermand why was it concluded that the point of action will be (3) and (4) and not (1) and (2)? The reason is that in young children the possibilities of their sustaining strategies for mentally grouping or associating the overt countermand with the stimulus rather than with
the response can be assumed to be less than with an adult. If such strategies are adopted they can be plausibly assumed to be less stable than with an adult. On this basis the point of action of the countermand can be assumed to vary randomly, sometimes helping to define the stimulus, sometimes interfering with the response organisation.

This now raises the further question of why the countermand should be assumed to cause more trouble to the motor performance than the command. In this case the command would be the word 'blue', and this too must be assumed to have a random point of action. Sometimes the command will impinge at point (1), that is, on the analysis of the stimulus. The result of this is that it would interfere with the correct identification of the stimulus, and thus ultimately undermine the response by feeding an incorrect input to the decision mechanism. In order to justify the conclusion that commands will not interfere as much as countermands two assumptions are necessary. The first is that the initial colour naming response will be well established and over-learned, so it will be highly resistant to interference by comparison with the more vulnerable 'temporary connections'. The second assumption concerns the detailed structure of the inner self-instruction that has been represented by the words 'red, so blue'. On the basis of Vygotsky's study of inner speech (1962, esp. pp. 100, 139, 145) the self-instruction will first
be formulated as something like, 'If I see the red I must press the blue,' then it will become, 'If red then blue,' then, 'red, blue,' and finally it will be abbreviated to just, 'blue'. The principle underlying the sequence of abbreviations is a generalisation of Vygotsky’s law of the predominance of predication and the omission of subjects in inner speech. That which is apparent and present to the speaker does not require mentioning: 'Inner speech is condensed, abbreviated speech... it is almost entirely predicative because the situation, the subject of thought, is always known to the thinker' (p. 100). The final form of the inner process of self-instruction should be represented by:

\[ S \rightarrow ('red') \rightarrow '...so blue' \rightarrow \text{motor } R \]

where the bracket around the word 'red' represents its protected status due to overlearning.

If these two assumptions are correct then, although the point of action of both the overt command and the overt countermand will range randomly across the whole process of stimulus identification and response organisation, it will only be the response side which will be vulnerable, and so the countermand will interfere more with performance than the command. In this way there will be produced a number of intrusive or opposite motor responses which would not have been present if the overt verbal response had not been required, and more intrusions will be associated with the countermands than with the commands.


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**Note:** On p. 6 there is a quotation from Weiss (1929) taken from Goss (1961). Goss has omitted two words from the original. The original reads, "The speech mechanism that produces the word food thus serves two purposes..." and so does not require the bracketed words added to Goss's version.